Fecal Coliform and Total Phosphorus TMDLs
Kickemuit Reservoir, Rhode Island (RI0007034L-01)
Upper Kickemuit River (RI 0007034R-01)
Kickemuit River (MA 61-08_2004)

DRAFT

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LIST OF ACRONYMS AND TERMS

BCWA = Bristol County Water Authority

BMP = Best Management Practice, the schedule of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of and impacts upon waters of the State. BMPs also include treatment requirements, operating procedures, and practices to control runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage (as defined in RIDEM's Water Quality Regulations).

Clean Water Act = the Federal Water Pollution Act (33 U.S.C. § 1251) et seq. and all amendments thereto.

Designated uses = those uses specified in water quality standards for each water body whether or not they are being attained. In no case shall assimilation or transport of pollutants be considered a designated use.

EPA = the United States Environmental Protection Agency

Fecal coliform = bacteria found in the intestinal tracts of warm-blooded animals. Their presence in water or sludge is an indicator of pollution and possible contamination by pathogens, which are disease-causing organisms.

LA = Load allocation, the portion of a receiving water's loading capacity that is allocated either to nonpoint sources of pollution or to natural background sources.

Loading capacity = the maximum pollutant loading that a surface water can receive without violating water quality standards.

MADEP = Massachusetts Department of Environmental Protection

MOS = Margin of Safety. Because bacteria levels are variable, it is possible that the specified reductions may not be adequate to allow water quality to meet standards. To account for this uncertainty, an additional reduction in bacteria levels beyond the required numeric bacteria concentration is specified. This can be achieved by using conservative assumptions, an explicitly allocated reduction, such as a level 10% below the standard, or a combination of both techniques.

MPN = Most Probable Number. An estimate of microbial density per unit volume of water sample, based on probability theory.

Natural background = all prevailing dynamic environmental conditions in a waterbody or segment, other than those human-made or human-induced. Natural background bacteria concentrations include contributions from wildlife and/or waterfowl.

Nonpoint source = any discharge of pollutants that does not meet the definition of point source in section 502. (14). of the Clean Water Act. Such sources are diffuse, and often associated with land use practices that carry pollutants to the waters of the state. They include but are not limited to, non-channelized land runoff, drainage, or snowmelt; atmospheric deposition; precipitation; and seepage.

Point source = any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation or vessel, or other floating craft, from which pollutants are or may be discharged. This term does not include return flows from irrigated agriculture.

RIDEM = Rhode Island Department of Environmental Management

RIDOH = Rhode Island Department of Health

Runoff = water that drains from an area as surface flow.

SDWA = Safe Drinking Water Act

TMDL = Total Maximum Daily Load, the amount of a pollutant that may be discharged into a waterbody without violating water quality standards. The TMDL is the sum of wasteload allocations for point sources, load allocations for nonpoint sources, and natural background. Also included is a margin of safety.

μg/L = a concentration unit of micrograms (one-millionth of a gram) pollutant (e.g. total phosphorus) per liter solution. One μg/L is equal to one-thousandth of a milligram per liter (mg/l). Hence, the total phosphorus standard of 0.025 mg/l = 25 μg/L.

USGS = United States Geological Survey

Water quality standard = provisions of state or federal law which consist of designated use and water quality criteria for the waters of the state. Water quality standards also consist of an antidegradation policy. Rhode Island's water quality regulations may be found at www.state.ri.us/dem/pubs/regs/index.htm#WR. Massachusetts' water quality regulations may be found at http://www.state.ma.us/dep/brp/wm/wqstds.htm.

WLA = Waste load allocation, the portion of a receiving water's loading capacity that is allocated to point sources of pollution.

ABSTRACT

This TMDL addresses water quality impairments in the Kickemuit River watershed associated with fecal coliform and excessive phosphorus loadings including excess algal growth/chlorophyll a, taste and odor, and turbidity. The Kickemuit River watershed extends northeast from the Town of Warren, Rhode Island into portions of the Towns of Swansea and Rehoboth, Massachusetts. Its waters in Rhode Island include the Lower Kickemuit Reservoir (also known as the Warren Reservoir and a tributary referred to in this document as the Upper Kickemuit River or western tributary, in the Town of Warren. The Kickemuit River extends north into southeastern Massachusetts, to its headwaters at the Anawan or Warren Upper Reservoir in the Town of Rehoboth. The watershed is comprised principally of forest (42.4% of its area), with significant areas of residential (16.0% medium to medium high density and 6.6% medium to low density) and agricultural (16.5%) use.

Waters in Rhode Island, including the Kickemuit Reservoir, the Kickemuit River, the Western tributary (Upper Kickemuit River) and the two unnamed RI tributaries are designated as Class A waters. The main stem of the river and tributary streams and reservoirs on the Massachusetts portion of the watershed are designated as Class B waters.

With the exception of the Warren Reservoir in Massachusetts, all reaches of the river and impoundments in Rhode Island and Massachusetts exceed the applicable water quality standards for fecal coliform bacteria. The reductions in bacteria loads in the river reaches range between 66% for the upper portion of the Lower Kickemuit Reservoir to more than 99% for the main stem of the river shortly before it enters Rhode Island.

The main stem of the river in Rhode Island is also impaired for nutrients. Total phosphorus load reductions to the Upper Kickemuit Reservoir and Lower Kickemuit Reservoir are 56% and 57%, respectively. Because an impairment exists in the downstream reservoirs, the Kickemuit River and Heath Brook in Massachusetts are also impaired for nutrients. The current load of phosphorus entering from the main stem of the river in Massachusetts and from two tributary streams in Rhode Island must be reduced by 53%, from 303 kg/yr to 142 kg/yr to allow the upper reservoir to meet the Rhode Island WQ standard for phosphorus. Similarly, the load from the Upper Kickemuit River (Western tributary) must be reduced by 59%, from 52 kg/yr to 19 kg/yr. The load reduction to the Lower Kickemuit Reservoir will be accomplished through a 52% reduction in the delivery of loads from upstream sources and a 30% reduction in loads from direct inputs and the Shad Factory Pipe source.

The Kickemuit Reservoir has also been identified as being impaired for turbidity and taste and odor problems since the early 1990s. Because the turbidity and taste and odor impairments result from the phosphorus sources or levels, the numeric targets for total phosphorus are assumed to address the turbidity and taste and odor impairments as well.

Implementation activities are categorized as follows:

<u>Stormwater runoff controls from streets and yards in the watershed.</u> Forty-one stormwater outfalls or other direct conveyances were identified in the watershed. Observations and data from outfalls in the Smoke Rise area in Massachusetts indicate that storm drains in that area impact the main stem of the river. An additional number of direct conveyances from roadways in the watershed that include Routes 6 and 195, Serpentine Road, and numerous local roads within the residential areas contribute phosphorus, sediments and bacteria loads to adjacent surface waters via storm runoff. Operators of small municipal separate storm sewer systems (MS4s) in regulated areas must develop stormwater management plans and obtain permits for those MS4s. In the Rhode Island portion of the watershed, the entire area of the Town of Warren is subject to the Phase II NPDES stormwater requirements. Whereas in the Massachusetts portion of the watershed, not all areas are designated urban areas, and thus are not currently subject to the Phase II NPDES stormwater requirements. This TMDL recommends that the Massachusetts DEP require permits for MS4s in the areas outside of the designated urban areas that contribute to the violation of water quality standards in the Kickemuit River system. Through a nonpoint source pollution abatement (319) grant, the Town of Warren is assessing stormwater abatement opportunities for the Serpentine Road drainage pipes that contribute stormwater runoff to the Kickemuit Reservoir.

<u>Septic systems.</u> Septic systems in the Smoke Rise and Mont Fair housing developments have a significant impact on phosphorus and bacteria levels in the river. The Swansea Board of Health shall continue to institute Massachusetts' Title 5 regulations, which require the upgrading of failed septic systems at the time of property transfer. The use of advanced treatment systems that provide reduced nutrient and bacteria loads in effluent should be used in areas adjacent to the river or its tributaries. The town should also continue the monitoring and follow through on individual septic system problems and failures, particularly in these two housing developments adjacent to the river and seek permanent solutions to eliminate improperly functioning systems in the watershed.

<u>Measures to control loadings from agricultural operations.</u> A number of farms have the potential or are currently causing nutrient, bacteria and sediment impacts to the Kickemuit River and its tributaries. In both Rhode Island and Massachusetts, farms have been identified for follow-up with recommended actions including the proper control and disposal of manure, restricting livestock's access to streams, stream bank stabilization, and the establishment of vegetative buffers along stream banks. Public education on the impacts that poor housekeeping practices have on these waterbodies is essential in reducing pollution from these sources. All identified farms will be referred to either the Rhode Island Department of Environmental Management's Division of Agriculture or the Massachusetts Division of Food and Agriculture for appropriate follow-up.

This TMDL relies upon a phased approach to an implementation plan to meet water quality goals. The corresponding response to reductions in total phosphorus and fecal coliform bacteria concentrations must be measured as remedial actions are implemented. Reductions in sediment loadings and the previously discussed phosphorus and bacteria concentration reductions will result in reduced turbidity levels which will improve the source water's taste and odor. As may be appropriate, additional recommendations will be required if standards are not met as a result of the implementation plan presented within this TMDL.

1.0 INTRODUCTION

Section 303(d) of the Clean Water Act (CWA) and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) requires states to develop Total Maximum Daily Loads (TMDLs) for water bodies that are not meeting water quality standards. The objective of a TMDL is to establish water-quality-based limits for pollutant loadings that allow the impaired waterbody to meet standards. This TMDL addresses water quality impairments associated with excessive phosphorus, sediments and bacteria (i.e. fecal coliform) loadings to water bodies in the headwaters of the Kickemuit Reservoir in eastern Rhode Island and southeastern Massachusetts, and the impairments to the Upper and Lower segments of the Kickemuit Reservoir itself.

The Kickemuit Reservoir plays an important role in providing drinking water to residents of Bristol, Warren and Barrington, Rhode Island. The Kickemuit Reservoir is the terminal downstream reservoir in a series of reservoirs located in both Rhode Island and Massachusetts that supply raw water to the Bristol County Water Authority (BCWA). BCWA treats the water and sends it to residential, commercial, and industrial customers in the three communities. Although BCWA is now able to purchase drinking water from the City of Providence, Rhode Island during times of peak demand, a majority of its water is still supplied through the Kickemuit Reservoir system. Current RI State laws require that the reservoir system be maintained as a drinking water supply. In addition the CWA would require that existing uses be maintained. Currently the BCWA treats the upper and lower Kickemuit Reservoirs with an aquatic herbicide (K-Tea) on a monthly basis. It should also be noted that upon demand, inter-basin transfer of waters from the Shad factory Pond in the Palmer watershed to the Kickemuit Reservoir also occurs via a direct pipeline connection.

1.1. Study Area

The study area includes the Kickemuit Reservoir (upper and lower reservoirs and is also known as the Warren Reservoir), the Kickemuit River (Massachusetts and Rhode Island portions), and its tributaries: the Upper Kickemuit River or Western Tributary, Heath Brook and two unnamed tributaries in Rhode Island. The Kickemuit Reservoir is located in the Town of Warren in eastern Rhode Island. The Kickemuit River watershed extends northeast from Rhode Island into portions of Swansea and Rehoboth, Massachusetts (Figure 1.1). The Kickemuit Reservoir is divided into two sections commonly referred to in this report as the upper and lower reservoirs.

1.2. Pollutants of Concern

The pollutants of concern in the Kickemuit Reservoir are excess algal growth/chlorophyll a, phosphorus, pathogens, turbidity, and taste and odor. Fecal coliform is a parameter used by RIDEM and MADEP as an indicator of pathogen contamination. Total phosphorus is a parameter used by RIDEM as an indicator of excessive nutrient enrichment, as it is typically the limiting nutrient to algal growth in the freshwater environment. Sediments along with algae caused by excessive phosphorus impair water clarity and its suitability for drinking water. This impact is measured using the turbidity parameter. For purposes of this TMDL, the total phosphorus criterion will also be used as a surrogate for excess algal growth/ chlorophyll a, taste and odor, and turbidity, as these impairments, documented in Rhode Island's 303(d) list, largely result from excessive phosphorus loadings. The Upper Kickemuit River (western tributary) is listed as impaired for pathogens only. Massachusetts's 2004 303(d) list identifies Massachusetts reaches of the Kickemuit River as impaired for pathogens.

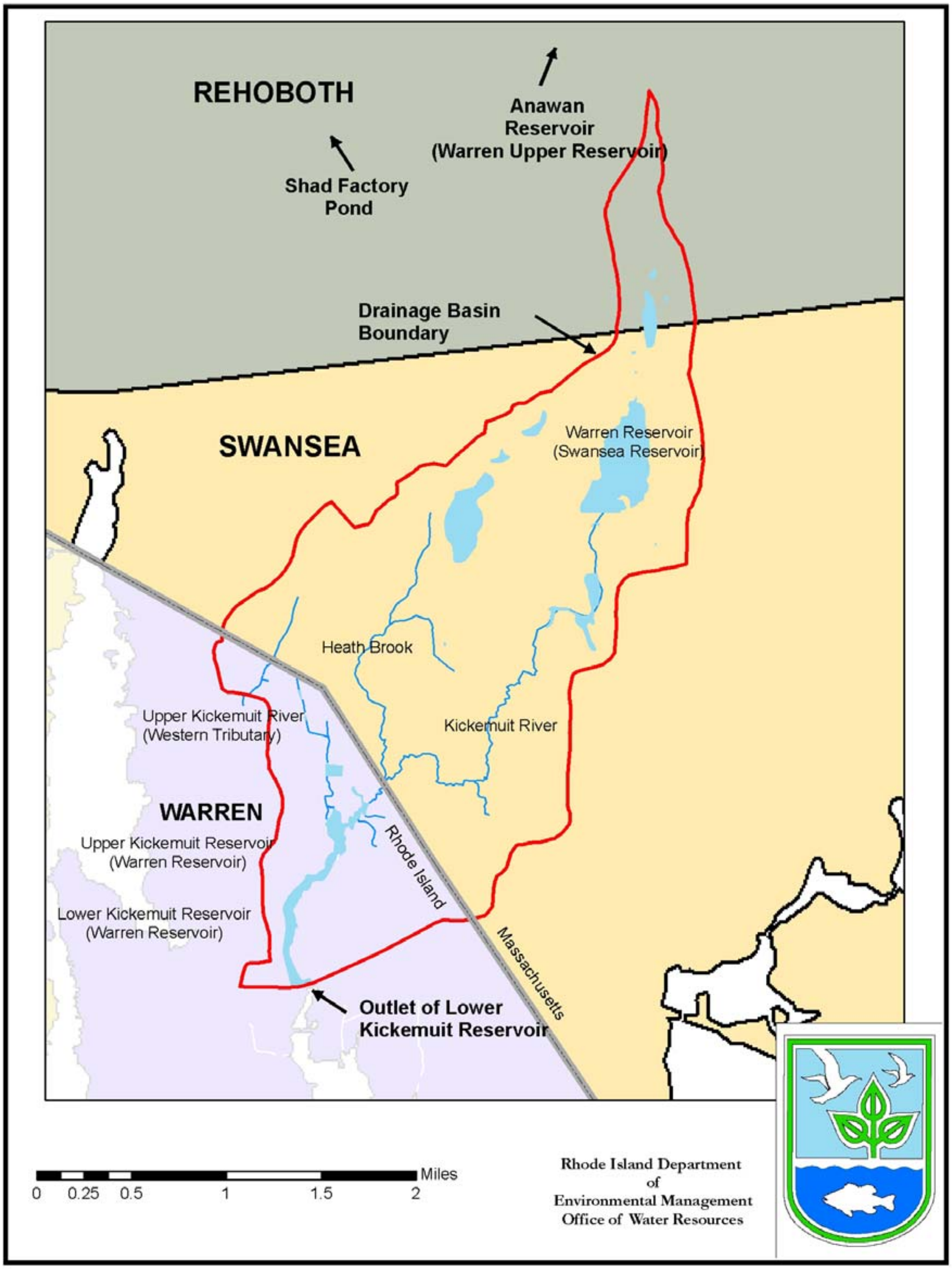
Table 1.1 Waterbody IDs and Impairments

Water Body Name	Water Body ID	Listed Impairment 2002, 303(d) List
Kickemuit Reservoir (Warren Reservoir)	RI0007034L-01	EXCESS ALGAL GROWTH/CHL-A, PHOSPHORUS, PATHOGENS, TURBIDITY, TASTE AND ODOR
Upper Kickemuit River	RI0007034R-01	PATHOGENS, BIODIVERSITY IMPACTS
Kickamuit River (6134500)	MA61-08_2002 Outlet Warren Reservoir, Swansea, to Rhode Island line. 2.8 miles	PATHOGENS

1.3. Priority Ranking

Both RIDEM and MADEP consider their respective portions of the Kickemuit Reservoir and River as high priorities for TMDL development. Rhode Island has placed the Kickemuit Reservoir and Upper Kickemuit River (Western Tributary) in Group 1 of its 2002 303(d) list of impaired waters, with a targeted priority for TMDL development. Massachusetts identifies the Kickemuit River (Outlet Warren Reservoir, Swansea, to Rhode Island line, Swansea, MA/ Warren, RI) as a "Category 5" water requiring a TMDL

Figure 1-1 The Kickemuit Reservoir watershed.



1.4. Applicable Water Quality Standards

Designated Uses

The Kickemuit Reservoir, the Kickemuit River, the western tributary referred to in Rhode Island as the Upper Kickemuit River, and the two unnamed RI tributaries are designated as Class A waters. Class A waters are designated as a source of public drinking water supply, for primary and secondary contact recreational activities and for fish and wildlife habitat. They shall be suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These waters shall have good aesthetic value. Class A waters used for public drinking water supply may be subject to restricted recreational use by State and local authorities.

Tributary streams and reservoirs on the Massachusetts portion of the watershed are designated as Class B waters by the State of Massachusetts. These waters are designated as habitat for fish, other aquatic life, and wildlife, and for primary and secondary contact recreation. Where designated they shall be suitable as a source of public water supply with appropriate treatment. They shall be suitable for irrigation and other agricultural uses and for compatible industrial cooling and process uses. These waters shall have consistently good aesthetic value.

Water Quality Criteria

<u>Rhode Island portion of watershed</u>

Fecal coliform – Not to exceed a geometric mean value of 20 MPN/100 ml and not more than 10% of the samples shall exceed a value of 200 MPN/100 ml.

Total Phosphorus – Rhode Island has a numeric standard for total phosphorus and a narrative standard for nutrients that are applicable to this area:

a) Average TP shall not exceed 0.025 mg/l in any lake, pond, kettlehole or reservoir, and average TP in tributaries at the point where they enter such bodies of water shall not cause exceedance of this phosphorus criteria, except as naturally occurs, unless the Director determines, on a site-specific basis, that a different value for phosphorus is necessary to prevent cultural eutrophication.

b) None in such concentration that would impair any uses specifically assigned to said Class, or cause undesirable or nuisance aquatic species associated with cultural eutrophication, nor cause exceedance of the criterion of (a) above in a downstream lake, pond, or reservoir. New discharges of wastes containing phosphates will not be permitted into or immediately upstream of lakes or ponds. Phosphates shall be removed from existing discharges to the extent that such removal is or may become technically and reasonably feasible.

Taste and Odor - None [taste and odor] other than from natural origin and none associated with nuisance algal species.

Turbidity - None in such concentrations that would impair any usages specifically assigned to this class. Turbidity not to exceed 5 NTU over background.

Massachusetts portion of watershed

Fecal coliform – the Class B water quality criteria for fecal coliform bacteria are not to exceed a geometric mean of 200 organisms per 100 ml in any representative set of samples and no more than 10 percent of the samples may exceed 400 organisms per 100 ml.

Total Phosphorus - Massachusetts does not have a specific numeric criterion for phosphorus, however its water quality standards contain the following clauses for aesthetics and nutrients that are applicable to all waters:

Aesthetics - All surface waters shall be free from pollutants in concentrations or combinations that settle to form objectionable deposits; float as debris, scum or other matter to form nuisances; produce objectionable odor, color, taste or turbidity; or produce undesirable or nuisance species of aquatic life.

Bottom Pollutants or Alterations - All surface waters shall be free from pollutants in concentrations or combinations or from alterations that adversely affect the physical or chemical nature of the bottom, interfere with the propagation of fish or shellfish, or adversely affect populations of non-mobile or sessile benthic organisms.

Nutrients - Shall not exceed the site-specific limits necessary to control accelerated or cultural eutrophication

Color and Turbidity - These waters shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this Class.

Taste and Odor - None in such concentrations or combinations that are aesthetically objectionable, that would impair any use assigned to this Class, or that would cause tainting or undesirable flavors in the edible portions of aquatic life.

Antidegradation
As designated drinking water supplies the Kickemuit Reservoir and its tributaries are identified as Special Resource Protection Waters (SRPWs) by Rhode Island. As SRPWs, these waters are afforded special protections under Rule 18, *Antidegradation of Water Quality Standards.* Rhode Island's antidegradation policy, requires that at the

Tier 1 level, any existing in-stream water uses and level of surface water quality necessary to protect existing uses, shall be maintained and protected.

Under Tier 2 ½ of Rhode Island's antidegradation policy, additional protection applies to SRPWs. Tier 2 ½ states that there shall be no measurable degradation of the existing water quality necessary to protect the characteristic(s) which cause the waterbody to be designated as an SRPW. Public drinking water suppliers may undertake temporary and short-term activities within the boundary perimeter of a public drinking water supply impoundment for essential maintenance or to address emergency conditions in order to prevent adverse effects on public health or safety, provided that these activities comply with the requirements of Tier 1 and Tier 2 of the policy.

The waters of the Kickemuit River in Massachusetts are not afforded special designation; Massachusetts' first level of protection therefore applies: In all cases existing uses and the level of water quality necessary to protect the existing uses shall be maintained and protected. Item (5) of the antidegradation provisions pertains to eutrophication:

> From and after the date 314 CMR 4.00 becomes effective there shall be no new or increased point source discharge of nutrients, primarily phosphorus and nitrogen, directly to lakes and ponds. There shall be no new or increased point source discharge to tributaries of lakes or ponds that would encourage cultural eutrophication or the growth of weeds or algae in these lakes or ponds. Any existing point source discharge containing nutrients in concentrations which encourage eutrophication or growth of weeds or algae shall be provided with the highest and best practical treatment to remove such nutrients. *Activities which result in the nonpoint source discharge of nutrients to lakes and ponds shall be provided with all reasonable best management practices for nonpoint source control.* (Italics added)

Numeric Water Quality Target

In Rhode Island waters, the fecal coliform water quality target is set at the Class A standard [not to exceed a geometric mean value of 20 MPN/100 ml and not more than 10% of the samples shall exceed a value of 200 MPN/100 ml]. In Massachusetts, the water quality target is set at the Class B standard [not to exceed a geometric mean of 200 organisms per 100 ml in any representative set of samples and no more than 10 percent of the samples may exceed 400 organisms per 100 ml]. At the RI-MA border, however, the waters of the Kickemuit River and those tributaries that originate in Massachusetts must meet the Rhode Island standard as they leave Massachusetts.

For total phosphorus, the numeric water quality target was set at the standard [average TP shall not exceed 0.025 mg/L in any lake, pond, kettle hole or reservoir] in the Upper and Lower Kickemuit Reservoirs. The numeric TP target for the Kickemuit River at the point of entry to the upper reservoir is set at 0.0225 mg/l (WQ standard plus 10% MOS).

For turbidity the numeric water quality target is set at the Rhode Island standard [not to exceed 5 NTU over background], and taste and odor is targeted as none that is from other than natural causes.

2.0 DESCRIPTION OF STUDY AREA

The Kickemuit Reservoir and River watershed consists of approximately 5,500 acres, which includes the tidal portion of the Kickemuit River. Approximately half the drainage area (2360 acres) is located in Rhode Island. Figure 1.1 shows the study area with the Rhode Island fresh water sub-basin delineated to illustrate the area of contribution to the water-bodies of concern within this TMDL. The area of the Rhode Island Kickemuit River fresh water sub-basin is approximately 725 acres. The area in Massachusetts and Rhode Island that contributes to the river is approximately 3316 acres.

The Kickemuit River from the Child Street bridge (RI Route 103) north to the RI-MA border, including the Kickemuit Reservoir are identified as water body RI0007034. The Upper Kickemuit River (water body RI0007034R-01) is a tributary that originates at the state line to the northwest of the Upper Kickemuit Reservoir. Two unnamed tributaries located to the east of the river within Rhode Island are identified as waterbody RI0007034R-02.

The Lower Kickemuit Reservoir is the terminal reservoir in a series of four reservoirs located in both Rhode Island and Massachusetts. The four reservoirs supply raw water to the Bristol County Water Authority (BCWA) water treatment plant, which withdraws water from the downstream end of the Lower Kickemuit Reservoir. The Warren Upper (Anawan Reservoir) and Shad Factory Reservoirs, located in Rehoboth, Massachusetts, collect flow from approximately 37 square miles of the upper Palmer River watershed. The Shad Factory Reservoir, which is the terminal reservoir within the upper Palmer River watershed, conveys water to the Kickemuit Reservoir through seven miles of 18, 20, and 21-inch pipeline. During the summer months, a significant portion of the water flowing into the Lower Kickemuit Reservoir is supplied by the Shad Factory Reservoir.

Approximately 80 percent of the local watershed is located in Swansea and Rehoboth, Massachusetts, and 20 percent is located in Warren, Rhode Island. The Warren Reservoir, also known as the Swansea Reservoir, MA is located near the northern end of this local watershed. Water is released from the reservoir when needed and flows through a natural streambed approximately 3 ½ miles to the Kickemuit Reservoir. This stream, referred to as the Kickemuit River on USGS topographic maps, has a width of 5 to 10 feet. This river is identified as the Kickemuit River (segment ID MA61-08_2004) on the list of impaired waters, category 5 requiring a TMDL, as impaired for pathogens (Massachusetts Year 2004 Integrated List of Waters).

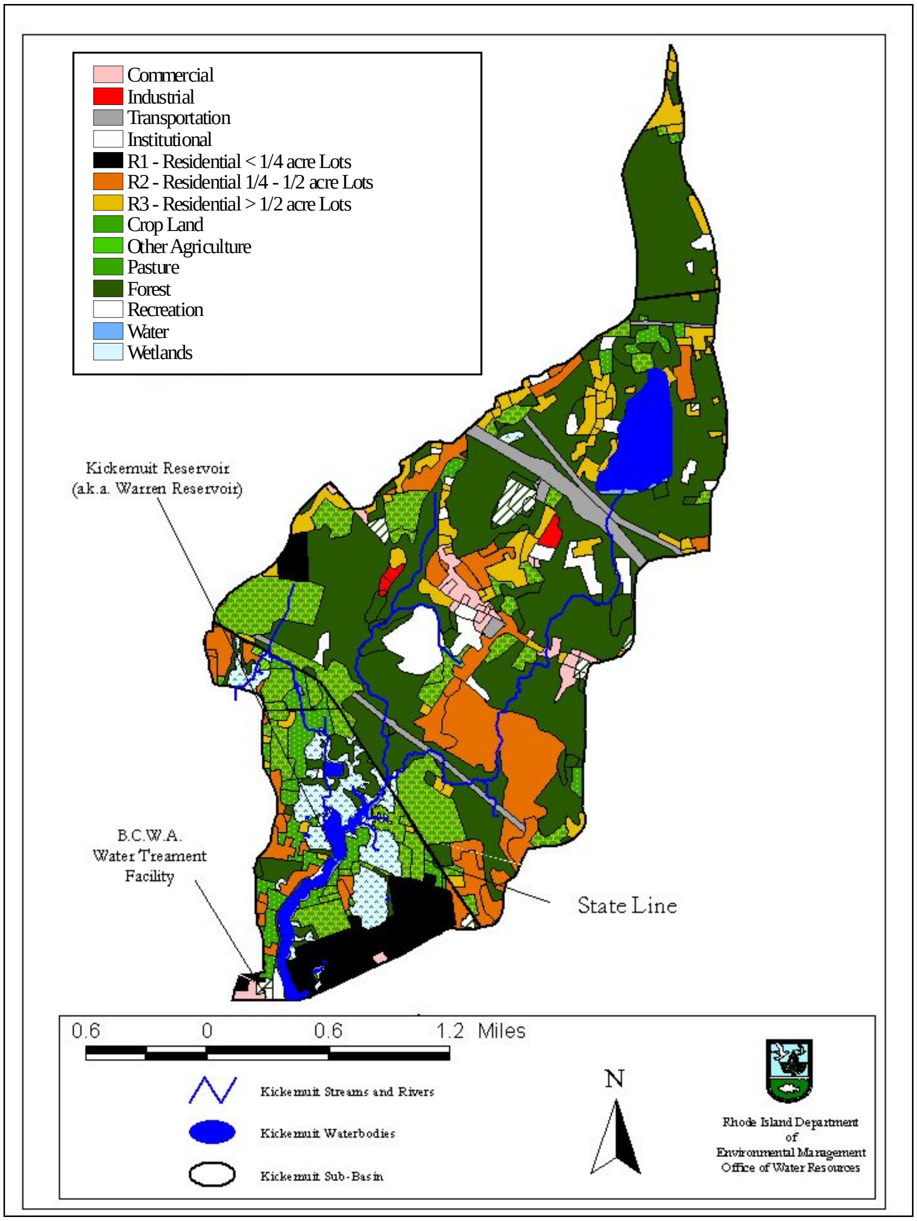
As the river flows southwest from the Warren (Swansea) Reservoir, it combines with an unnamed tributary and Heath Brook just north of the state line before discharging into the Upper Kickemuit Reservoir. Water leaving the Upper Kickemuit Reservoir passes through dual culverts under School House Road as it enters the Lower Kickemuit Reservoir. The lower reservoir discharges to the tidal waters of the Kickemuit River over the dam immediately north of the Route 103 bridge in Warren, Rhode Island.

The distribution of land uses in the Kickemuit sub-basin is shown in Figure 2.2. Table 2.1 summarizes the areas of each land use. Presently, 16.5% of the sub-basin is used for some type of agricultural use, such as pasture or cropland. Forest makes up the most predominant land use, comprising 42.4% of the sub-basin. Medium to medium high density residential land uses comprise 16.0% of the total area, while 6.6% is medium to low density residential. The remaining areas are a mixture of commercial uses, developed recreation, cemeteries and forest. A small area of 3.23 acres is used as a poultry operation at the headwaters of the Upper Kickemuit River. The BCWA water treatment facility is located at the southwest corner of the lower Kickemuit Reservoir adjacent to Rt. 103 in Warren.

Table 2.1 Land Use in the Kickemuit Watershed

Land Use Description	Total Acres	Total Acres in Category	% Total Acres
Cropland	401.5		
Pasture	144.0		
		545.5	16.5
Forest	1404.8		
		1404.8	42.4
Residential Medium Density R2	376.3		
Residential Medium High Density R1	153.7		
Residential Medium Low Density R3	220.1		
		750.1	22.5
Commercial	55.7		
Industrial	13.2		
Institutional	128.3		
Transportation	101.6		
		298.8	9.0
Recreation	35.0		
Water	130.9		
Wetlands	151.1		
		317.0	9.6
Total		3315.9	100

Figure 2-1 Land uses in the Kickemuit sub-basin.



3.0 PRESENT CONDITION OF THE WATERBODY

3.1. Monitoring Conducted During 2000

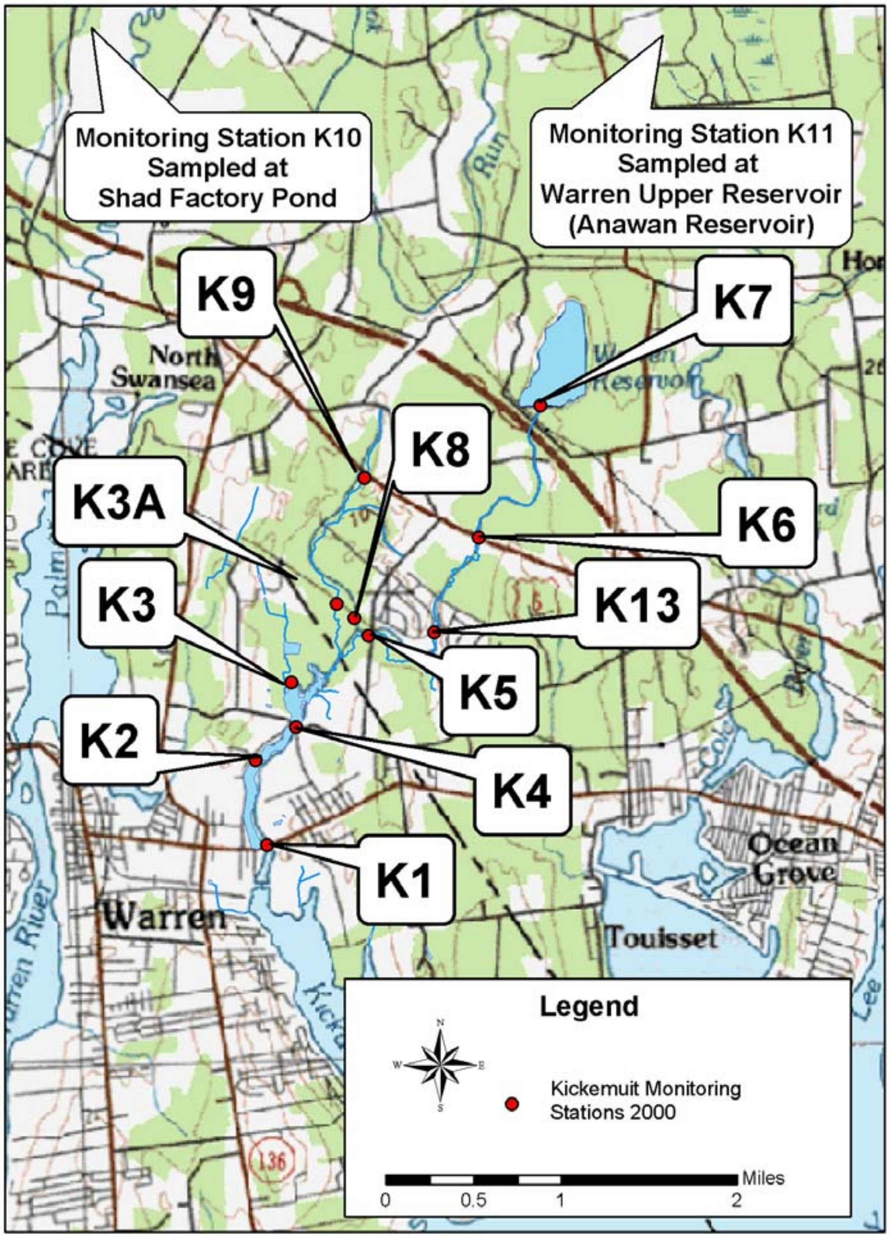
Due to the limited availability of historical data, a plan for additional monitoring was developed as a first step in the TMDL development process. The preliminary data review and proposed monitoring plan were presented at a public meeting in Warren, Rhode Island on March 23, 2000. The monitoring plan was modified based on feedback obtained during and after this public meeting. A Quality Assurance Project Plan (QAPP) was developed during the spring of 2000 (EPA, 2000). RIDEM, EPA, and contractor personnel conducted monitoring during the 2000 field season.

Monitoring stations were located at key locations in the drainage basin. Based on the need to define water quality for flow diverted into the Kickemuit Reservoir from the Shad Factory Reservoir and in response to a request from the public, monitoring stations were added at the outlet of the Shad Factory (K10) and Warren Upper (K11) Reservoirs. A monitoring station (K7) was also placed at the outlet of the Warren (a.k.a. Swansea) Reservoir, which drains directly into the North Branch of the Kickemuit River in Swansea. Detailed descriptions of each monitoring station are given in the data assessment report (RIDEM, 2001). Figure 3.1 shows the locations of these monitoring stations.

The water quality characterization was made from nine daytime surveys conducted at 13 locations in the streams and reservoirs of the sub-basin. Eight surveys were conducted at approximate two-week intervals, regardless of weather conditions (dry or wet). These periodic surveys were conducted on May 17, June 7, June 19, July 6, July 20, August 10, August 24, and September 14, 2000. For the purposes of this study, a wet weather day was defined as one with a rainfall total exceeding 0.03” on the day of sampling, and a cumulative total of greater than 0.2” on the three preceding days. Based on these criteria, the 6/7, 7/20, and 8/10 data were found to be representative of wet weather, with three-day rainfall totals of 2.58, 0.45, 0.60, and 1.09 inches, respectively. An additional wet weather study was also conducted on September 15, 2000 to further quantify the impacts of a significant rainfall event on water quality and flows in the drainage basin. Stream flow measurements suggest that runoff to the surface streams was insignificant during all but the June 7 and September 15 monitoring surveys, even though significant rainfall occurred prior to or even during some of the other surveys. The 5/17, 6/19, 7/6, 8/24, and 9/14 dates were set as dry weather days, with 3-day cumulative rainfall values of 0.15, 0.10, 0.09, 0.17, and 0.16 inches, respectively.

Water quality characteristics were calculated using the original criteria for the determination of dry or wet weather conditions. Calculations in the TMDL analysis (Section 4.0) evaluated a geometric mean of the results without regard to weather conditions.

Figure 3-1 Water quality monitoring stations sampled during the 2000 monitoring program.



3.2. Current Water Quality

<u>Fecal Coliform Conditions</u>

Fecal coliform data collected during the 2000 monitoring are presented in Table 3.1.

Table 3.1 Fecal Coliform monitoring results (MPN /100 ml) for the Kickemuit watershed (2000).

(Note: Original criteria used to determine wet weather conditions)

Station	5/17 dry	6/7 wet	6/19 dry	7/6 dry	7/20 wet	8/10 wet	8/24 dry	9/14 dry	9/15 wet	wet	wet
									R1	R2	R3
Rhode Island Stations											
K 1	80	130	20	25	32	29	16	25	4000	780	240
K 2	90	**970**	37	4	**40**	36	50	150			
K 3		11750					440		13000	7000	6000
K 4	70	1090	30	57	18	37	10	162	2300	4000	200
Massachusetts Stations											
K3A										60000	7000
K 5	870	3300	1600	630	260	**5200**	**5000**	890	15000	13000	23000
K 6		1200	447	150	70	1400	2600	810	2900	4400	3700
K 7	4	47	15	2	7	10	3	6			
K 8			234								
K 9			384	140							
K 10	40	9150	400	1650	*5*	8	10	**43**			
K 11	9	47	22	*0.5*	*0.5*	7	6	2			
K 13						5000					
Dup.		**960**			**37**	**3400**	**6300**	**30**			

Numbers in Italics are expressed as half the detection limit

Number in bold are calculated from pairs of replicates. Both values are used to calculate statistics

Table 3.2 presents statistics calculated from the 2000 monitoring study data. The farthest upstream sample on the main stem of the Kickemuit River was station K7, at the outlet of the Warren Reservoir. Fecal coliform concentrations were relatively low, with a dry weather geometric mean value of 5 fc/100 ml and a wet weather geometric mean concentration of 15 fc/100 ml. Geometric mean concentrations increased significantly at the next downstream station, K6, to values of 613 fc/100 ml (dry) and 1331 fc/100 ml (wet). The increase continued to K5, with dry and wet weather geometric mean concentrations of 1313 fc/100 ml and 5210 fc/100 ml, respectively. Three tributary streams enter the river between K5 and the next main stem station, K4. Stations K8 (unnamed brook), K3A, K9 (Heath Brook) and K3 (Upper Kickemuit or Western

Table 3.2 Fecal Coliform statistics calculated from the 2000 monitoring data.

Note: Original criteria used to determine wet weather events

		All survey data			Dry weather surveys			Wet weather surveys		
Station	State	Geometric Mean, (fc/100 ml)	90th % concentration, (fc/100 ml)	Sample Count	Geometric Mean, (fc/100 ml)	90th % concentration, (fc/100 ml)	Sample Count	Geometric Mean, (fc/100 ml)	90th % concentration, (fc/100 ml)	Sample Count
K 1	RI	***84***	***780***	11	***28***	***58***	5	***212***	***2390***	6
K 2	RI	***59***	***396***	8	***40***	***126***	5	***112***	***784***	3
K 3	RI	***4899***	***12500***	5	***440***	***440***	1	***8950***	***12625***	4
K 3A	MA	***20494***	***54700***	2	NS	NS	0	***20494***	***54700***	2
K 4	RI	***134***	***2300***	11	***45***	***125***	5	***332***	***3150***	6
K 5	MA	***2785***	***15000***	11	***1313***	***3640***	5	***5210***	***19000***	6
K 6	MA	***976***	***3770***	10	***613***	***2063***	4	***1331***	***4050***	6
K 7	MA	7	25	8	5	11	5	15	40	3
K 8	MA	***234***	234	1	***234***	234	1	NS	NS	0
K 9	MA	***232***	360	2	***232***	360	2	NS	NS	0
K 10	MA	90	***3900***	8	103	***1150***	5	72	***7322***	3
K 11	MA	5	30	8	4	17	5	5	39	3
K 13	MA	***5000***	***5000***	1	NS	NS	0	***5000***	***5000***	1

"Bold Italic" values exceed state's applicable water quality criteria
NS – Not Sampled

Tributary) characterized these small tributaries. These tributaries were sampled less regularly during the study because they were frequently dry. Below station K5, the river crosses into Rhode Island then empties into the Upper Kickemuit Reservoir. Station K4 was located at the outlet of the Upper Kickemuit Reservoir. Fecal coliform concentrations dropped significantly between K5 and this location, where dry and wet weather geometric concentrations were 45 fc/100 ml and 332 fc/100 ml, respectively. At the two remaining instream stations, fecal coliform concentrations continued to decline somewhat. At station K2, midway down the Lower Kickemuit Reservoir, dry and wet weather concentrations were 40 fc/100 ml and 112 fc/100 ml. Dry and wet weather concentrations at station K1 at the mouth of the Lower Kickemuit Reservoir were 28 fc/100 ml and 212 fc/100 ml, respectively.

Algal and Phosphorus Conditions

Excessive nutrient enrichment can result in nuisance growths of algae and other aquatic plants. Nuisance growth of algae also exacerbates turbidity. Increased turbidity complicates treatment processes for drinking water supplies and creates undesirable tastes and odors. The nutrients principally responsible for excessive growths of algae are nitrogen and phosphorus. Both nutrients are needed for plant growth, and are taken up by plants on a molecular ratio of 16 atoms of nitrogen for each atom of phosphorus, known as the Redfield Ratio. On a mass basis, this ratio is 7.2:1 N: P. This relationship is significant because if the supply of one nutrient is exhausted, continued plant growth is inhibited. The nutrient in shorter supply is known as the limiting nutrient. In fresh water environments, phosphorus is typically the limiting nutrient. Results of sampling conducted during the 2000 monitoring season indicate that this is the case in both the upper and lower segments of the Kickemuit Reservoir. If the supply of phosphorus is reduced, the frequency and occurrence of nuisance algal blooms will also be reduced.

As previously discussed in this report, Rhode Island has a numeric water quality standard for phosphorus that is set to protect waters from excessive nutrient enrichment. This standard states that average total phosphorus shall not exceed 25 ug/L (= 0.025 mg/l, see definition in list of acronyms and terms) in any lake, pond, kettle or reservoir. Massachusetts does not have a numeric criterion for phosphorus concentration in fresh waters. During the 2000 study, main stem total phosphorus concentrations were consistently above the 25 ug/l threshold value at monitoring stations in the Kickemuit Reservoir, including both the upper and lower segments (Table 3.3). Means and other statistics of the data for all surveys are presented in Table 3.4. At all monitoring stations, TP results exceeded the phosphorus limit except station K11 located at the outfall of the Warren Upper Reservoir. Looking along the axis of the river, TP starts at its lowest value at station K7 at the outlet of the Warren Reservoir, 28 ug/l. TP increases slightly to 34 ug/l at station K6, then increases sharply to 100 ug/l at K5. Concentrations at K5 are highest on wet weather days of July 20, August 10, and September 15. In contrast, wet weather concentrations at stations K7 and K6 are not significantly higher than the dry weather values.

Table 3.3 Total Phosphorus data for Kickemuit River waters (2000).

Station	State	5/17 Dry	6/7 Wet	6/19 Dry	7/6 Dry	7/20 Wet	8/10 Wet	8/24 Dry	9/14 Dry	9/15		
										Wet	Wet	Wet
K1	RI	44	42	68	48	37	31	29	29	34	32	36
K2	RI	36	112	99	46	54	32	26	210			
K3	RI		105					40		187	70	97
K3A	MA										49	42
K4	RI	55	93	104	97	90	30	28	51	48	37	42
K5	MA	48	74	82	113	100	189	73	38	171	143	65
K6	MA		29	46	45	40	34	35	28	32	25	25
K7	MA	25	30	32	27	28	33	27	25			
K8	MA			132								
K9	MA			35	48							
K10	MA	34	115	84	75	98	52	36	33			
K11	MA	18	69	19	17	22	19	17	12			
K13	MA						58					

Table 3.4 Total Phosphorus statistics by station for 2000.

	All surveys			
Station	Mean, ug/l	Minimum, ug/l	Maximum, ug/l	Sample Count
K 1	***39***	29	68	11
K 2	***77***	26	210	8
K 3	***100***	40	187	5
K 3A	***46***	42	49	2
K 4	***61***	28	104	11
K 5	***100***	38	189	11
K 6	***34***	25	46	10
K 7	***28***	25	33	8
K 8	***132***	132	132	1
K 9	***42***	35	48	2
K 10	***66***	33	115	8
K 11	24	12	69	8

Note: "***Bold Italic***" values exceed the RI water quality standard of 25 ug/l TP; Massachusetts does not have a numeric TP standard.

Chlorophyll a is a useful measure of algal biomass. Seasonal averaged values that exceed 9 ug/L are typically considered to represent eutrophic or over-enriched conditions. Peak chlorophyll a concentrations in oligotrophic lakes may range from 1.5 to 10.5 ug/l, while values greater that that would indicate eutrophic conditions. (EPA Guidance, Lake and Reservoir Restoration

Manual, 1990). An in-lake chlorophyll a goal of 9 ug/l is considered to be sufficiently low enough so that algae production will not cause nuisance amounts which could then lead to or cause problems with taste and odor and treatment for drinking water supply. Chlorophyll a data collected at stations K1 and K2 in the Lower Kickemuit Reservoir during the 2000 surveys arepresented in Table 3.5. The results are strongly influenced by high values (32.2 and 37.4 ug/l) seen at both stations in the reservoir on June 19 that push the seasonal mean concentration above the 10 ug/l level.

Table 3.5 Chlorophyll a data by station in the Lower Kickemuit Reservoir (2000).

Date	Chlorophyll Concentration in ug/L							
	Mean	5/17	6/7	6/19	7/6	7/20	8/10	8/24
K1	12.0	7.6	8.0	37.4	4.5	8.9	5.4	0.0
K2	11.2	7.7	**15.5**	32.2	8.8	7.1	3.8	3.2
Duplicate			**7.3**					

Bold data indicates duplicate samples

Dissolved oxygen conditions

In-situ measurements of dissolved oxygen were made where possible at the instream stations during the 2000 study. Measurements were made at the water surface between the hours of 9 AM and 3 PM. It should be noted that concentrations would be lower at other times of day, particularly during the early morning hours, and that surface waters typically contain higher levels of dissolved oxygen than bottom waters due to exposure to air and wind action. Dissolved oxygen levels in the hypolimnia of stratified lakes may typically be below the instantaneous water quality standard during the summer season. A dissolved oxygen level less than 5.0 mg/l in the hypolimnion does not necessarily indicate a water quality violation if due to natural causes (RIDEM, 1997). The results presented in Table 3.6 indicate that the instantaneous minimum DO standard of 5.0 mg/l was violated at station 4 (outlet of the Upper Kickemuit Reservoir) during five of the seven surveys. DO concentrations were lowest (2.6 mg/l) during the September 14, 2000 dry weather survey. DO concentrations at all other stations met the standard, however, on July 20, 2000, DO at station 2 (northern station in Lower Kickemuit Reservoir) was 5.0 mg/l.

Table 3.6 Dissolved oxygen measurements made during 2000 surveys.

Date	Dissolved Oxygen (mg/l)							
	05/17	06/07	06/19	07/06	07/20	08/10	08/24	09/14
Station								
K1	6.8	6.1	9.4	7.2	5.8	7.2	8.2	6.7
K2	7.3	5.1	8.1	7	5	6	7.4	6.1
K3		6.7						
K4		5.8	***4.6***	***4.7***	***3.4***	***4.9***	6.6	***2.6***
K5	8.5	8.5	7.7	6.1	6.1	6.4	8.3	8.8
K6		5.8	6.4	5.1	6.5	6.4	5.9	6
K7	8.4							
K8								
K9								
K10	8		5.2					
K11	7.4		6.4					

Values in ***"Bold Italics"*** indicate violations of the water quality standard (5.0 mg/l)

Turbidity

The 2000 monitoring did not measure turbidity directly. Other measurements of water clarity were recorded, however. Secchi depth was measured at stations K1 and K2 in the lower Kickemuit Reservoir with depths varying from a low of 0.9m (2.0 ft) to a high of 1.5m (4.9 ft). Sampling was conducted between May and the first two weeks of June, with subsequent sampling not completed due to extensive macrophytes in the water column (NES, 2001). Total suspended solids (TSS) was measured throughout the watershed during the 2000 monitoring program. TSS can be used as a surrogate for turbidity. A report published by the Water Resources Research Institute, found that 68% of the variability associated with turbidity was attributable to TSS. A 10 mg/l increase in TSS corresponded to a turbidity increase of 6 NTU (Reed, J., et al, 1983). The results for all stations sampled during dry and wet weather are presented in Table 3.7. Wet weather TSS data indicates a substantial increase in volume of sediments in samples taken during storm events, whereas dry weather levels are significantly lower. This is a direct indication that sediments in stormwater directly influence turbidity levels in the tributaries and downstream reservoirs.

Table 3.7 TSS measurements made during 2000 surveys.

Date	Total Suspended Solids (mg/l)										
Station	05/17 dry	06/07 wet	06/19 dry	07/06 dry	07/20 wet	08/10 wet	08/24 dry	09/14 wet	9/15 wet R1	9/15 wet R2	9/15 wet R3
K1	1	3	3	1	ND	2	ND	3	21	62	8
K2	ND	**4**	5	2	**ND**	1	ND	25			
K3	-	2	-	-	-	-	ND	-	54	27	8
K3A	-	-	-	-	-	-	-	-	-	26	19
K4	ND	9	5	1	ND	ND	2	2	17	51	3
K5	ND	16	5	2	ND	**8**	ND	3	139	25	16
K6	-	5	97	2	2	3	2	1	27	12	69
K7	ND	3	3	ND	ND	6	ND	5	-	-	-
K8	ND	-	3	-	-	-	-	-	-	-	-
K9	-	-	1	ND	-	-	-	-	-	-	-
K10	ND	3	5	8	2	2	2	5	-	-	-
K11	ND	2	1	2	ND	2	-	1	-	-	-
DUP	ND	**4**	-	-	**ND**	**10**	15	**1**	-	-	-
K13	-	-	-	-	-	-	-	-	-	-	-
DUP		0%				11%		0%			

Note: Bold values indicate at which station each duplicate was collected. "- " indicate that no sample was collected. "ND" means concentration was below the detection limit for the given analysis. DUP indicates percent error for duplicate samples.

3.3. Pollution Sources

The Kickemuit Reservoir, the Kickemuit River and the numerous tributaries are affected by a variety of pollution sources. Non-point and point sources of pollution include stormwater runoff from disturbed or eroding watersheds that carry sediments, phosphorus and bacteria from developed and agricultural lands within the watershed. Residential and commercial areas contribute bacteria, phosphorus, and sediment loads to the river through overland flow during and after rainstorms. The loads originate from septic systems, particularly failing systems that break out onto the surface, lawn fertilizers, pet waste, and wildlife. Failing septic systems in residential and commercial areas may also contribute bacteria and phosphorus to the river and tributaries through groundwater. Sediment loads likely originate from roadways (road sand) and other impervious surfaces in the watershed and are conveyed to the river in stormwater. Phosphorus conveyed through the atmosphere is deposited in particulate (wet and dry weather) and dissolved (wet weather) form on all watershed surfaces. This source is not explicitly addressed in this study, however.

Point sources of pollution were identified through pipe surveys conducted by EPA personnel during the summer of 2001, and by comparing the sampling data at the surface water stations described in section 3.3 above with land use information available from RIGIS and Mass GIS. The pipe survey information is presented below, followed by summaries of sources by reach in section 3.4.2. Staff walking along the length of the river and tributaries conducted the survey. Both pipes and concentrated surface flow locations were identified. Pipe diameters were measured and recorded along with other distinguishing information. A majority of the sources were located using GPS receivers. The results of the survey are presented in Figure 3.2 and Table 3.8. The locations of sources 1 through 9 in Figure 3.2 are approximate positions taken from descriptions provided by EPA staff.

RIDEM and EPA staff conducted additional source sampling in the summer of 2003 at five locations in the watershed following a rain event of 0.35” on the previous day. These results are presented in Table 3.9. The map ID refers to outfalls described in Table 3.8 unless otherwise noted.

Figure 3-2 Stormwater outfalls and other direct conveyances in the Kickemuit River watershed.

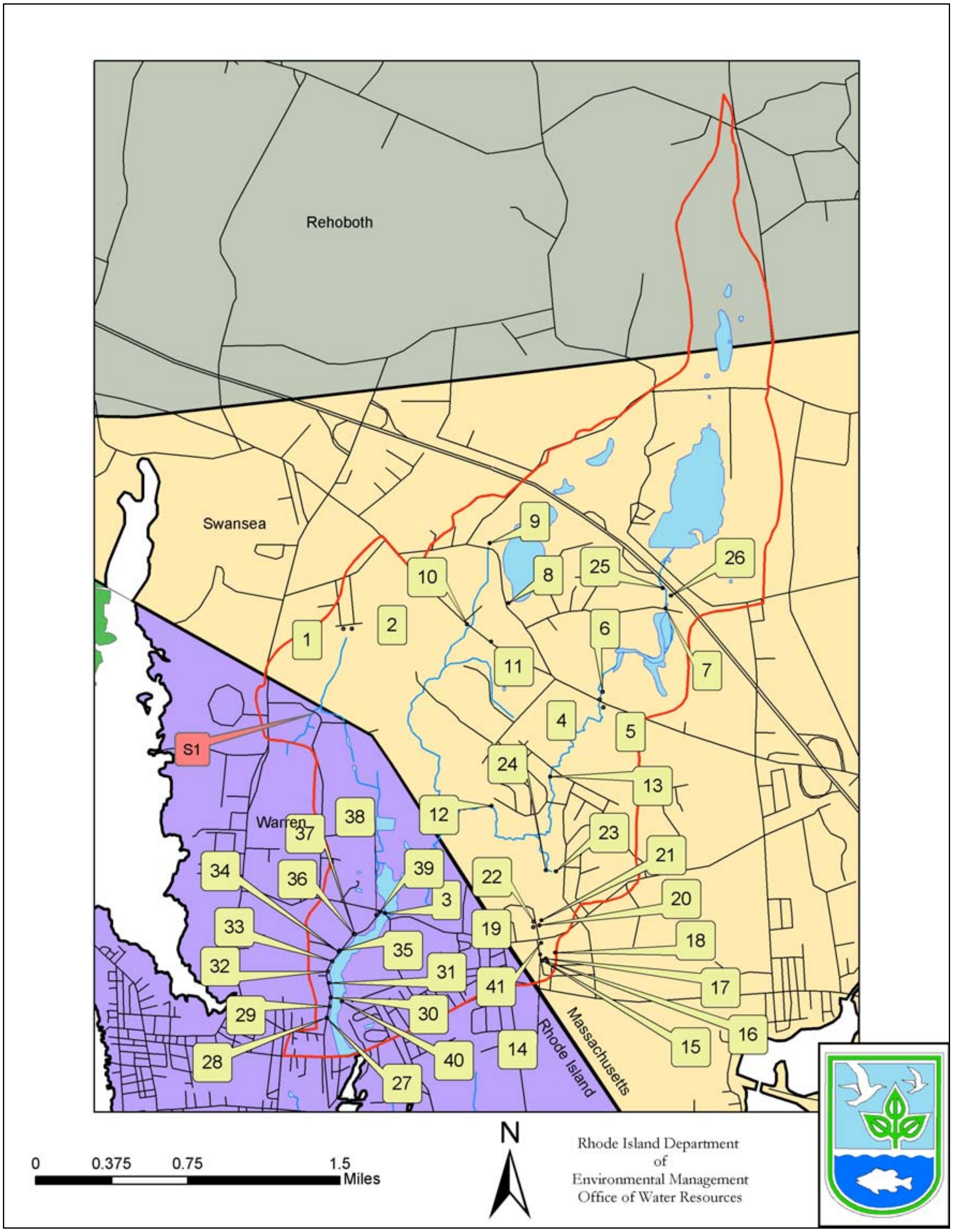


Table 3.8 Description of stormwater outfalls and other direct conveyances in the Kickemuit watershed (2001).

Map ID	Latitude	Longitude	Site Description
	Dec Deg	Dec Deg	
1	ND	ND	storm pipe (22" ID) Joanne Lane
2	ND	ND	storm pipe (22" ID) Joanne Lane
3	ND	ND	overland flow from roadway
4	ND	ND	catch basin; drains to Kickemuit; in gas station parking lot 10 ft. S of rte. 6
5	ND	ND	overland flow from parking lot
6	ND	ND	catch basin; appears to convey runoff from rte. 6 into the Kickemuit River.
7	ND	ND	overland flow from roadway; appears to be minimal landuse undeveloped.
8	ND	ND	overland flow from roadway, minimal compared to other sources.
9	ND	ND	overland flow from roadway, minimal compared to other sources.
10	41.760093	-71.25171	several catch basins on rte. 6; convey runoff to W branch of Heath Brook.
11	41.758811	-71.24966	several catch basins on rte. 6; convey runoff to E branch of Heath Brook.
12	41.747078	-71.24968	storm pipe (36" ID)
13	41.749166	-71.2441	storm pipe (18" ID)
14	41.736465	-71.24509	storm pipe (12" ID)
15	41.736068	-71.24487	runoff channel - located in residential backyard
16	41.735943	-71.24438	storm pipe (15" ID)
17	41.736185	-71.24456	runoff channel
18	41.736615	-71.24366	storm pipe (12" ID)
19	41.738444	-71.24575	overland flow from roadway
20	41.738556	-71.24515	runoff channel
21	41.738913	-71.24499	runoff channel
22	41.738844	-71.24571	storm pipe (18" ID)
23	41.742386	-71.24357	storm pipe (30" ID)
24	41.742468	-71.24452	runoff channel
25	41.762604	-71.23335	storm pipe (8" ID)
26	41.762033	-71.23258	storm pipe (8" ID) - partially below ground
27	41.731969	-71.26541	runoff channel - hand dug
28	41.732022	-71.26541	runoff channel - hand dug
29	41.732826	-71.26515	storm pipe (12" ID)
30	41.733474	-71.26503	storm pipe (12" ID)
31	41.734495	-71.26521	storm pipe (12" ID)
32	41.735324	-71.26532	storm pipe
33	41.736043	-71.26489	storm pipe
34	41.736715	-71.26425	overland flow from roadway
35	41.736807	-71.26417	storm pipe (12") - drains wetland area
36	41.738001	-71.26281	runoff channel
37	41.73798	-71.26272	storm pipe (8")
38	41.739333	-71.26069	storm pipe (8")
39	41.739563	-71.26035	storm pipe (16")
40	41.733198	-71.26397	runoff channel - appears to convey substantial volume
41	41.737308	-71.24503	road culvert

Table 3.9 August 14, 2003 source sampling results for fecal coliform

Map ID	Site Description	Results (fc/100 ml)
1	22" Storm drain Joanne Lane, Swansea, MA	5400
2	22" Storm drain Joanne Lane, Swansea, MA	2300
12	36" Storm drain Smoke Rise Circle, Swansea, MA	16000
S1	Southern portion of Upper Kickemuit River (Western Tributary) downstream of animal pasture, Birch Swamp Road, Warren RI	49000
12A	Kickemuit River upstream of Map ID 12	3400

3.4. Summary of Sources by Reach

The schematic shown in Figure 3.3 displays the Kickemuit River system in graphic form. Each river reach is shown with its associated sampling stations and direct sources (tributaries). The following text summarizes the data and describes in more detail the sources of bacteria and phosphorus loadings.

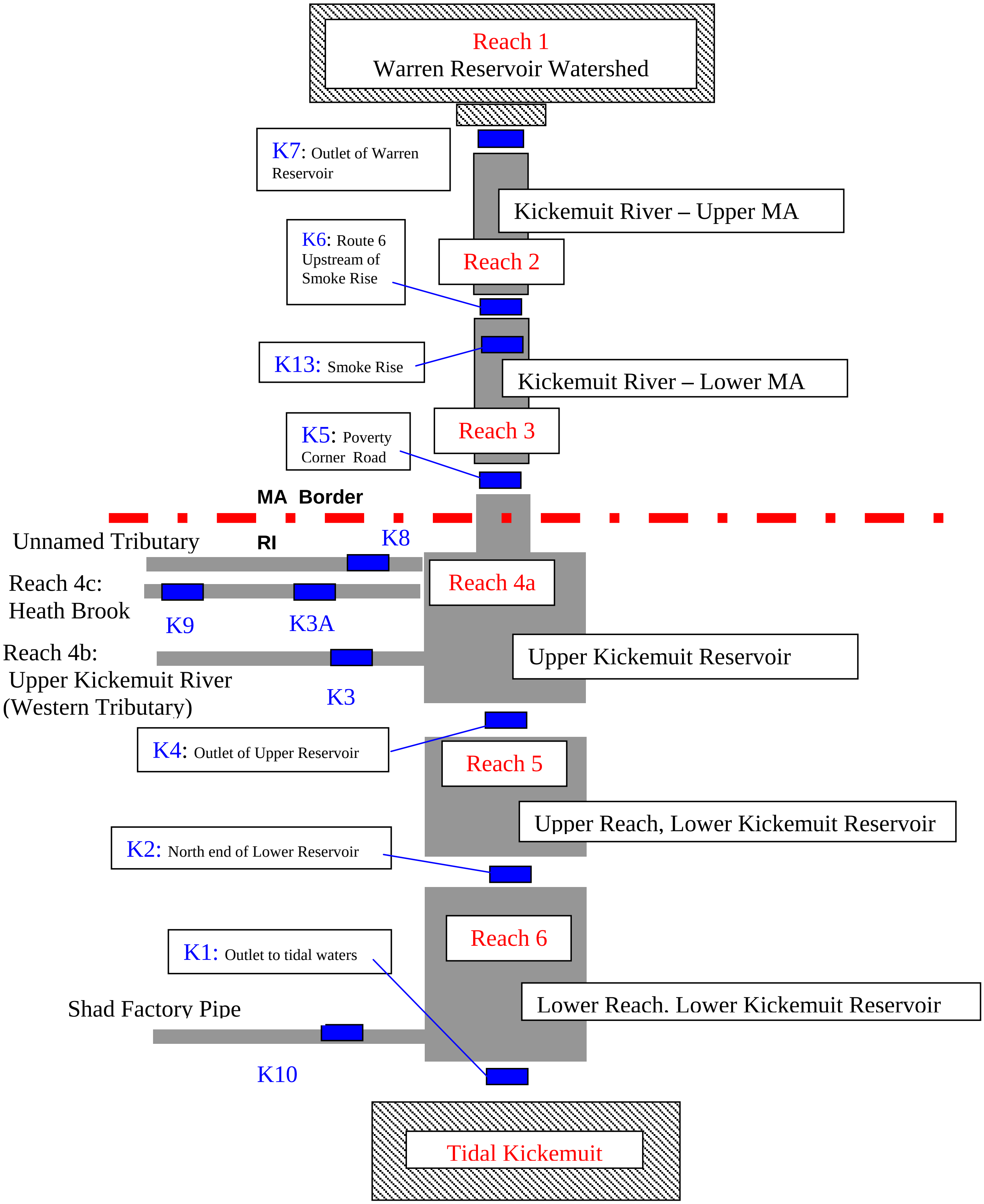
Although turbidity is not discussed specifically in the following summaries, it should be noted that the sources of increased turbidity due to sediments in surface waters are associated with or caused by those sources of phosphorus and bacteria. Sources of the excess sediment loads that contribute to increases in turbidity would be included in the agricultural and stormwater sources.

<u>Reach 1 - Warren Reservoir Watershed</u>
Represented by monitoring station K7 at the outlet of the Warren Reservoir. Sampling at this monitoring station indicates that bacteria standards are attained (7 fc/100ml). It is not known whether exceedance of the fecal coliform criteria occurs at other points in this waterbody due to a lack of sampling data. This station is located in Massachusetts, which does not have a numeric TP water quality standard. The mean concentration is greater than the RI TP standard of 25 ug/l.

<u>Reach 2 – Kickemuit River- upper MA reach</u>
Represented by monitoring station K6, this waterbody segment exceeds MA criteria for fecal coliform bacteria during all weather conditions. This station is located in Massachusetts, which does not have a numeric TP water quality standard. The mean concentration is greater than the RI TP standard of 25 ug/l. Sources of both bacteria and phosphorus include wildlife that inhabit the open and wetland areas that border this reach of the river, and stormwater runoff from adjacent roadways.

<u>Reach 3 - Kickemuit River – lower MA reach</u>
Represented by monitoring station K5 at Poverty Corner Road. This segment exceeds criteria for fecal coliform bacteria during all weather conditions. Bacteria and phosphorus sources to this reach include stormwater runoff, failing septic systems, wildlife, and agricultural landuse activities in close proximity to the stream where adequate riparian buffers are lacking. This segment of the Kickemuit River is directly adjacent to a large un-sewered residential development that has a history of septic system problems and failures.

Figure 3-3 Schematic view of the Kickemuit River System



The Smoke Rise housing development located in the Town of Swansea, MA and the adjacent Mont Fair Circle development together total approximately 400 dwelling units. These residential developments were built in the early 1970's. Title V standards that regulate the design, construction and monitoring rules for septic systems were not promulgated in Massachusetts until 1975. Swansea officials have completed wastewater facilities plan updates that have identified a high rate of failing septic systems (46-57%) town wide (Wastewater Facilities Plan Update, Swansea MA, 1980 and 2000, section 1.B).

Available information indicates that the large housing developments bordering the river and at least one of its tributaries are probably the dominant bacteria and phosphorus sources to this reach. The 2000 sampling data show a consistent increase in fecal coliform and phosphorus concentrations in the river as it passes by these developments. The fecal coliform data in Table 3.2 show geometric mean fecal coliform concentrations increasing from 976 fc/100 ml at station K6 to 3011 fc/100 ml at K5. The main stem of the Kickemuit River in this reach was also sampled on one occasion during dry weather in the summer of 2003 at a location downstream of K13 and upstream of K5. This single grab sample (Map ID 12A, Table 3-8) had a bacteria level of 3400 fc/100 ml. A grab taken on the same day at storm drain 12, which serves Smoke Rise Circle a short distance downstream, had a concentration of 16,000 fc/100 ml. Personnel conducting the pipe survey in the Smoke Rise development in 2001 noted that a number of the storm drains smelled of sewage (Basile, personal communication). Total phosphorus concentrations similarly increase from 34 ug/l to 100 ug/l along the same reach. The 2000 monitoring data by Baker (NES, 2001) also shows marked increases in nitrates and ortho-phosphorus between K6 and K5. Inorganic nitrogen transport is generally conservative in oxygenated groundwater environments, whereas phosphate is strongly retained through adsorption and precipitation reactions, reaching background levels within distances of 10 to 100 m (Wieskel and Howes, 1992). The observed increase in inorganic phosphorus concentration may indicate that large sources are either very close to the river's edge or that septic systems are clogging, with the result that septage is surfacing and is transported to the river under wet and dry weather conditions via surface flows, e.g. through the storm drain system. These scenarios are consistent with the increase in fecal coliform concentrations through this reach and with the presence of significant dry weather fecal coliform concentrations in area storm drains during dry weather.

Students in the Environmental Studies Program at Brown University (Hausman et al, 2002) conducted file reviews of 223 of the approximately 400 residential lots within the Smoke Rise and Mt. Fair Circle area. Their focus was on location (i.e. within 300 ft of the river), nature of repairs (if any), system design, and soils data.

Of the 223 systems reviewed by Hausman, et al:
- 60% were "original constructions," meaning that the only records on file were for the original construction (usually in the early 1970s).
- 37% of systems had been repaired, meaning that at least one element of the tank, piping, or leach field had been repaired or replaced.
- 3% of the systems were inspected, meaning that there was an inspection done but no record of repair on file.

The review further indicated that soil conditions in this area were very poor for septic systems, with a prevalence of low hydraulic conductivity (i.e. impermeable) soils and high water tables. When considered in combination, these pieces of information indicate a high likelihood that septic system failures adjacent to the river contribute to the fecal coliform and phosphorus water quality violations in this and downstream segments of the river.

Field observations made in the spring of 2002 by RIDEM personnel also confirmed that large numbers of domestic animals (dogs and cats) reside in these developments. Given the bacteria concentration increase in the reach between stations K7 and K6, it is reasonable to expect that wildlife and domestic animals also contribute to the increase in fecal coliform concentrations between stations K6 and K5.

<u>Reach 4a – Upper Kickemuit Reservoir</u>
Represented by monitoring station K4 at the outlet of the upper reservoir. This reach exceeds the fecal coliform during dry and wet weather and the total phosphorus criteria. Sources of bacteria and phosphorus include loadings from upstream segments (Kickemuit River, Heath Brook, and the Upper Kickemuit River (western tributary) and direct inputs from the drainage area immediately surrounding the reservoir. As mentioned above, the direct input estimate also includes loading from waterfowl and other wildlife that frequent the reservoir.

In addition to the direct inputs, there are three additional sources within this reach. They are identified on the schematic as: Unnamed tributary represented by station K8, Heath Brook represented by stations K9 and K3A, and the Upper Kickemuit River or western tributary represented by monitoring station K3. Model estimates of loading for total phosphorus (NES 2002) indicate that the greatest loading is coming from the Kickemuit River (217 kg/yr), followed by Heath Brook (86 kg/yr), the Upper Kickemuit River (western tributary) (52 kg/yr), and direct inputs (50 kg/yr). The unnamed tributary's contribution was included in the direct inputs of the drainage area and not as a separate source.

<u>Reach 4b - Upper Kickemuit River (Western Tributary)</u>
Represented by monitoring station K3, the Upper Kickemuit River or western tributary exceeds fecal coliform criteria during wet and dry weather and the total phosphorus criterion. As previously mentioned in this report, RI water quality standards state that phosphorus concentrations in tributary streams must not cause exceedance of the impoundment standard (25 ug/L) at the point of discharge to such a waterbody. The TP seasonal average at station K3 was 99.8 ug/l. The loading associated with the mean concentration of this tributary in concert with the main stem loading produces an exceedance of 25 ug/l in the Upper Kickemuit Reservoir. Sources of bacteria and phosphorus include stormwater runoff, wildlife, and agricultural land use activities in close proximity to the stream where good riparian buffers are lacking i.e., pasture (livestock, dairy farms in Massachusetts), and a poultry operation in Rhode Island.

<u>Reach 4c - Heath Brook</u>
Stations K3A and K9 represent this tributary. This tributary exceeds fecal coliform criteria during wet and dry weather and the total phosphorus criterion. Total phosphorus loads from this tributary contribute to water quality violations in the downstream waters of the Kickemuit Reservoir. Sources of bacteria and phosphorus include stormwater runoff, wildlife, and

agricultural landuse activities (i.e., pasture (livestock)) in close proximity to the stream where good riparian buffers are lacking. During field visits, RIDEM staff noted that a number of cattle had access to the stream immediately downstream of Route 6 in the Massachusetts portion of the watershed.

Using the data collected by the 2000 field studies, Baker (2002) adapted a loading and pollutant transport model to the Kickemuit River. The model estimated the annual TP load entering the Upper Kickemuit Reservoir at 405 kg/yr. The model estimated that a majority of the total loading to the upper reservoir was attributable to the main stem of the river. The contributions of Heath Brook were also significant. The majority of phosphorus enters this reach under wet weather conditions (NES, 2002).

Reach 5 - Upper reach, Lower Kickemuit Reservoir
Represented by monitoring station K2 at the north end of the lower reservoir, this exceeds fecal coliform criteria during wet and dry weather and the total phosphorus criterion. Sources of bacteria and phosphorus include loadings from the upper Kickemuit Reservoir, the numerous point sources identified along the shoreline (See Figure 3.2 and Table 3.8), and the direct inputs from the drainage area immediately surrounding the reservoir, which includes agricultural activities. The direct input estimate also includes loadings from waterfowl and other wildlife that frequent the reservoir.

Reach 6 – Lower reach, lower Kickemuit Reservoir
Represented by monitoring station K1, this reach exceeds fecal coliform criteria during wet and dry weather and the total phosphorus criterion. Sources of bacteria and phosphorus include loading from upstream segments, the Upper Kickemuit Reservoir, the Shad Factory Reservoir Pipe and direct inputs from the drainage area immediately surrounding the reservoir, which include dairy farms and other agricultural activities. There are fifteen direct discharge pipes located along this reach of the reservoir (Figure 3.2, Sources #27 - #40). The direct input estimate also includes loading from waterfowl and other wildlife that frequent the reservoir. According to model estimates of predicted loading for total phosphorus (NES, 2002), the greatest loading is coming from the Upper Kickemuit Reservoir (373 kg/yr), followed by the Shad Factory Reservoir (85 kg/yr), whereas the direct inputs contributed 29 kg/yr.

Shad Factory Reservoir
Represented by monitoring station K10. Sampling at this monitoring station indicates that criteria for fecal coliform are exceeded during all weather conditions. This waterbody is also listed on the Massachusetts 303(d) list for nutrients. The mean Total Phosphorus concentration at K10 is 66 ug/l. Pollutant sources in the Shad Factory watershed have not been identified.

Warren Upper (Anawan) Reservoir
Represented by monitoring station K11. Sampling at this monitoring station indicates that the bacteria standard is met (5 fc/100ml). It is not known whether exceedance of the fecal coliform criteria occurs at other points in this waterbody due to a lack of sampling data. The total phosphorus water quality standard is also met (24 ug/l) at the point of discharge from the reservoir.

In summary, the most notable sources of bacteria, phosphorus and sediments in the Kickemuit watershed are:

1. The numerous stormwater outfalls that convey yard and road runoff, including pollutants from failing septic systems. Of particular importance is stormwater runoff from developed areas adjacent to the Kickemuit River, the dairy farms and poultry operation on the Upper Kickemuit River (western tributary), and the numerous stormwater outfalls that discharge directly to the Lower Kickemuit Reservoir. The perimeter of the Lower Reservoir is poorly buffered from the impacts of surrounding land uses that include roadways and farms.

2. Failing septic systems, particularly in the reach between K6 and K5, which includes the Smoke Rise housing development and the adjacent Mont Fair Circle development.

3. Agricultural activities in close proximity to waterbodies where good riparian buffers are lacking, including:

    a. Direct access of livestock to Heath Brook, just south of Route 6.
    b. Cattle pasture on the southwest corner of the Lower Kickemuit Reservoir. During large rain events, runoff from this pasture washes directly into the Lower Reservoir in close proximity to the drinking water intake.
    c. Livestock that may have access to the Upper Kickemuit River (Western Tributary).
    d. A poultry operation located in the Upper Kickemuit River (Western Tributary).
    e. Tilling and farming operations in close proximity to shorelines with inadequate soil erosion and sedimentation controls.

4. Waterfowl and other wildlife, which appear to be most evident in their contribution to the significant rise in bacteria concentrations between K7 and K6.

5. The piped input from Shad Factory Reservoir.

3.5. Water Quality Impairments

<u>Fecal coliform</u>

Based on data collected during this study, all reaches of the river in Rhode Island are impaired for fecal coliform. These include the Lower and Upper Kickemuit Reservoir, the portion of the Kickemuit River located within Rhode Island and the Upper Kickemuit River (western tributary). The two tributaries located to the east of the Upper Kickemuit Reservoir were not characterized individually, however it is reasonable to expect that their water quality would be similar to other tributaries within the watershed due to their similar watershed conditions and land uses.

Water bodies impaired for fecal coliform in Massachusetts include the main stem of the Kickemuit River between the outlet of Warren Reservoir to the Rhode Island border (reaches 2 and 3), and Heath Brook. The condition of other smaller tributaries entering the main stem of the river in these reaches is assumed to be similar to that of the main stem.

Total phosphorus

In Rhode Island waters, the applicable phosphorus standard is a mean total phosphorus concentration of 25 ug/l. Based on the summary of mean total phosphorus concentration by station presented in Table 3.4, reaches 4a, 5, and 6 in Rhode Island are impaired. Mean total phosphorus concentrations at stations K1 and K2 (reaches 6 and 5) were 39and 77 ug/l, respectively. The Upper Kickemuit Reservoir, represented by station K4 (reach 4a) had a mean concentration of 61 ug/l. At their points of discharge to reach 4a, both the Upper Kickemuit River referred to as the western tributary represented by station K3 and the main stem of the Kickemuit River represented by station K5 (upstream in Massachusetts) had total phosphorus concentrations equal to 100 ug/l.

Massachusetts does not have a numeric criterion for total phosphorus concentration, however its regulations do contain a clause that specifies that waters …" *[shall not exceed the site-specific limits necessary to control accelerated or cultural eutrophication*"*]*. Given the determination that an impairment exists in the downstream reservoirs, the main stem of the Kickemuit River and Heath Brook in Massachusetts are also impaired for nutrients.

Turbidity and Taste and Odor

The Kickemuit Reservoir is impaired for turbidity and taste and odor. Although direct measurements for turbidity were not taken, historic data indicates that the water quality standard is not met. TSS data collected during the 2000 monitoring support this conclusion.

4.0 TMDL ANALYSIS

As described in EPA guidelines, a TMDL identifies the pollutant loading that a waterbody can assimilate per unit of time without violating water quality standards (40 C.F.R. 130.2). The TMDL is often defined as the sum of loads allocated to point sources (i.e. waste load allocation, WLA), loads allotted to nonpoint sources, including natural background sources (i.e. load allocation, LA), and a margin of safety (MOS). The loadings are required to be expressed as mass per time, toxicity, or other appropriate measures (40 C.F.R. 130.2[I]).

4.1. Establishing a Numeric Water Quality Target

Margin of Safety (MOS)

The MOS may be incorporated into the TMDL in two ways. One can implicitly incorporate the MOS by using conservative assumptions throughout the TMDL development process or one may explicitly allocate a portion of the TMDL as the MOS. This TMDL uses the former approach for bacteria and the latter approach for phosphorus.

- For bacteria, existing conditions (Table 3.2) are calculated from a data set that has more wet than dry surveys. Also the TMDL allocations are developed to meet the bacteria criteria during critical conditions when fecal coliform concentrations are typically higher. Lastly, no allowances were made for either bacterial decay or losses due to settling.
- For phosphorus, an explicit MOS of 10% (0.0225 mg/l) was included in the TMDL for loads entering reach 4a with the exception of direct inputs from the watershed and the loss to sediments in the upper reservoir.

Seasonal Variation/Critical Conditions

Critical conditions for fecal coliform occur during the summer months when concentrations are typically at their highest levels. Since the fecal coliform TMDL was developed to be protective of this critical time period, it will also be protective throughout the remainder of the year.

Critical conditions for phosphorus also occur during the growing season (April – October) when the frequency and occurrence of nuisance algal blooms is greatest. Since the total phosphorus TMDL was developed to be protective of this critical time period, it will also be protective throughout the remainder of the year. Critical conditions for turbidity are assumed to occur during the summer season when algal growth occurs and during wet weather conditions when sediment loads associated with stormwater are greatest.

Numeric Water Quality Target

Because the turbidity and taste and odor impairments result from the phosphorus sources or levels, the numeric targets listed below for total phosphorus are assumed to address the turbidity and taste and odor impairments as well.

Rhode Island portion of watershed
Fecal coliform – The numeric water quality target is set at the Class A standard [not to exceed a geometric mean value of 20 MPN/100 ml and not more than 10% of the samples shall exceed a value of 200 MPN/100 ml].

Total Phosphorus - The numeric water quality target for the Upper and Lower Kickemuit Reservoirs is set at the water quality standard [average TP shall not exceed 0.025 mg/L in any lake, pond, kettle hole or reservoir, and average TP in tributaries at the point where they enter such bodies of water shall not cause exceedance of this phosphorus criterion].

Massachusetts portion of watershed
Fecal coliform – The numeric water quality target is set at the Class B standard [shall not exceed a geometric mean of 200 organisms per 100 ml in any representative set of samples nor shall more than 10 percent of the samples exceed 400 organisms per 100 ml]. At the point where the Kickemuit River and its tributaries enter Rhode Island, the Rhode Island water quality standards for Class A waters must be met (20 MPN/100ml and less than 10% exceed 200 MPN/100ml).

Downstream of station K5, the Kickemuit River flows through a wetland complex. In that reach, it merges with Heath Brook and two other small tributaries before entering Rhode Island and the head of Upper Kickemuit Reservoir. Because K5 is the closest measurement point upstream of the border, the Rhode Island numeric fecal coliform criteria for Class A waters must be applied to the point where the river passes K5.

Total Phosphorus – To meet standards in downstream reaches, a numeric target of 22.5 ug/l is specified for Reach 3 at station K5 and for Heath Brook at station K3A.

Antidegradation Consideration
The Rhode Island Water Quality Standards has designated the waters of the Kickemuit Reservoir as Special Resource Protection Waters (SRPWs) due to their use as a public drinking water supply. In light of this designation, additional antidegradation criteria contained within the water quality standards apply. In addition to the Tier 1 criteria that all existing uses and any level of surface water quality necessary to protect those uses shall be maintained and protected, SRPWs shall also be afforded protection from measurable degradation of the existing water quality characteristic(s) that cause the waterbody to be designated as a SRPW. Public drinking water suppliers may undertake temporary and short-term activities within the boundary perimeter of a public drinking water impoundment for essential maintenance, or to address emergency conditions in order to prevent adverse effects on public health or safety.

4.2. Establishing the Allowable Load (TMDL)

The allowable load is defined as the maximum loading that a waterbody can receive without exceeding the numeric water quality criteria (40 C.F.R. 130.2(f)).

Fecal Coliform
For both Massachusetts and Rhode Island waters, the allowable load or loading capacity is expressed as a concentration set equal to the applicable state water quality standard for fecal coliform bacteria. As previously discussed, the loadings are required to be expressed as mass per

time, toxicity, or other appropriate measures (40 C.F.R. 130.2(i)). In the case of bacteria, it is appropriate to express a TMDL in terms of concentration for the following reasons:

- Expressing a bacteria TMDL in terms of concentration provides a direct link between existing water quality and the numeric water quality criteria;

- Using concentration in a bacteria TMDL is more relevant and consistent with water quality standards, which apply for a range of flow and environmental conditions; and

- Bacteria TMDLs expressed in terms of daily loads are typically more confusing to the public and more difficult to interpret, since they are completely dependent on flow conditions.

<u>Total Phosphorus</u>
The allowable load or loading capacity for this TMDL is based on an annual loading but accounts for a seasonal variability. Loadings over a shorter time period rather than an annual loading are critical to water quality due to the very short hydraulic residence time ranging from several days during winter and spring to approximately 2 weeks in mid-summer of this system. The loading is set on a seasonal basis; however, it is acknowledged that these loadings should be equally distributed over the course of a season so that short-term loadings do not have a negative impact on water quality. This is most important during the growing season (April-Oct) when ambient temperatures are warm enough to promote nuisance growths of algae and other aquatic plants. This is also the period in which dissolved oxygen levels within the reservoirs tend to decline, which can lead to the release of bound phosphorus from the sediments into the water column as an additional load if anoxic conditions occur.

4.3. Linking pollutant loading to the numeric water quality target

Extensive field surveys, water quality monitoring, and review of aerial photos and topographic maps were used to establish the link between pollutant sources and water quality impairments. In addition, computer modeling of watershed hydrology, loading of total phosphorus, and subsequent transport and assimilation within the streams and impoundments was conducted. This linkage establishes the basis for determining loading reductions needed to meet the numeric water quality standards.

4.4. Waste Load and Load Allocations

EPA guidance requires that load allocations be assigned to either point (wasteload) or nonpoint (Load) sources. There are no point sources within the watershed other than stormwater outfalls identified in Figure 3.1. For purposes of allocating the required reductions between point and nonpoint sources only, it is assumed that stormwater generated on developed land is a point source and storm water generated on undeveloped land is a nonpoint source. It is noted however that the resulting estimates do not alter the determination of point sources regulated under the NPDES Storm Water Program. Channelized stormwater associated with activities that are subject to Phases I and II of EPA's regulations for storm water discharges (whether on developed or undeveloped land) are regulated under the NPDES program as a point source, while unregulated and unchannelized stormwater are considered nonpoint sources. As described for fecal coliform below, the partitioning of the percent load reductions into WLAs and LAs for fecal coliform and phosphorus were based on GIS-based estimates of the impervious fraction of the associated subwatersheds.

Fecal Coliform

Watershed pollutant loading and receiving water computer modeling tools were developed in 2001-2002 for use in determining TMDL allocations for fecal coliform and total phosphorus in the upper Kickemuit watershed (NES, 2002). The model calibration for fecal coliform indicated that model predicted values were significantly different however from monitoring data collected during the 2000 field season. In the absence of a calibrated model, RIDEM has relied on data collected during 2000 to determine the bacteria allocations.

The first step in the allocation process was to divide the watershed into reaches. Each reach had at least one monitoring station that was assumed to be representative of water quality throughout the reach. Next, the reduction goal was determined by comparing existing monitoring data to the water quality target, and calculating the percent reduction needed to meet the target. Since the Massachusetts and Rhode Island water quality regulations specify both a geometric mean criterion and a 90^{th} percentile, at least two calculations were made for each monitoring station.

To address the first part of the water quality standard, geometric means were calculated from the combined set of dry and wet weather data for each monitoring station and compared to the water quality standard. The percent reductions necessary to meet the standard were determined. To address the second part of the standard, the 90^{th} percentile value was calculated from the combined set of dry and wet weather data for each station using the PERCENTILE function in Microsoft Excel and the percent reduction necessary to meet the standard were determined. For each reach, the greatest reduction necessary to meet both parts of the water quality standard was set as the TMDL allocation. Table 4.1 contains the results of those calculations for each of the reaches.

The fecal coliform allocations in this TMDL are calculated from observed concentrations at in stream stations and represent a reduction goal that is applicable to the composite of all point and nonpoint sources contributing to the water quality impairment. The reduction was further refined by establishing separate WLAs for segments that contain known point sources within each reach. In order to establish a waste load allocation (WLA) for point sources, impervious cover was calculated using RIGIS and MASSGIS data. This approach was used to estimate the percentage of the total load reduction to be accomplished through implementation of the WLA for each segment. Waste load and load allocations were then distributed to the appropriate water body segment within the watershed.

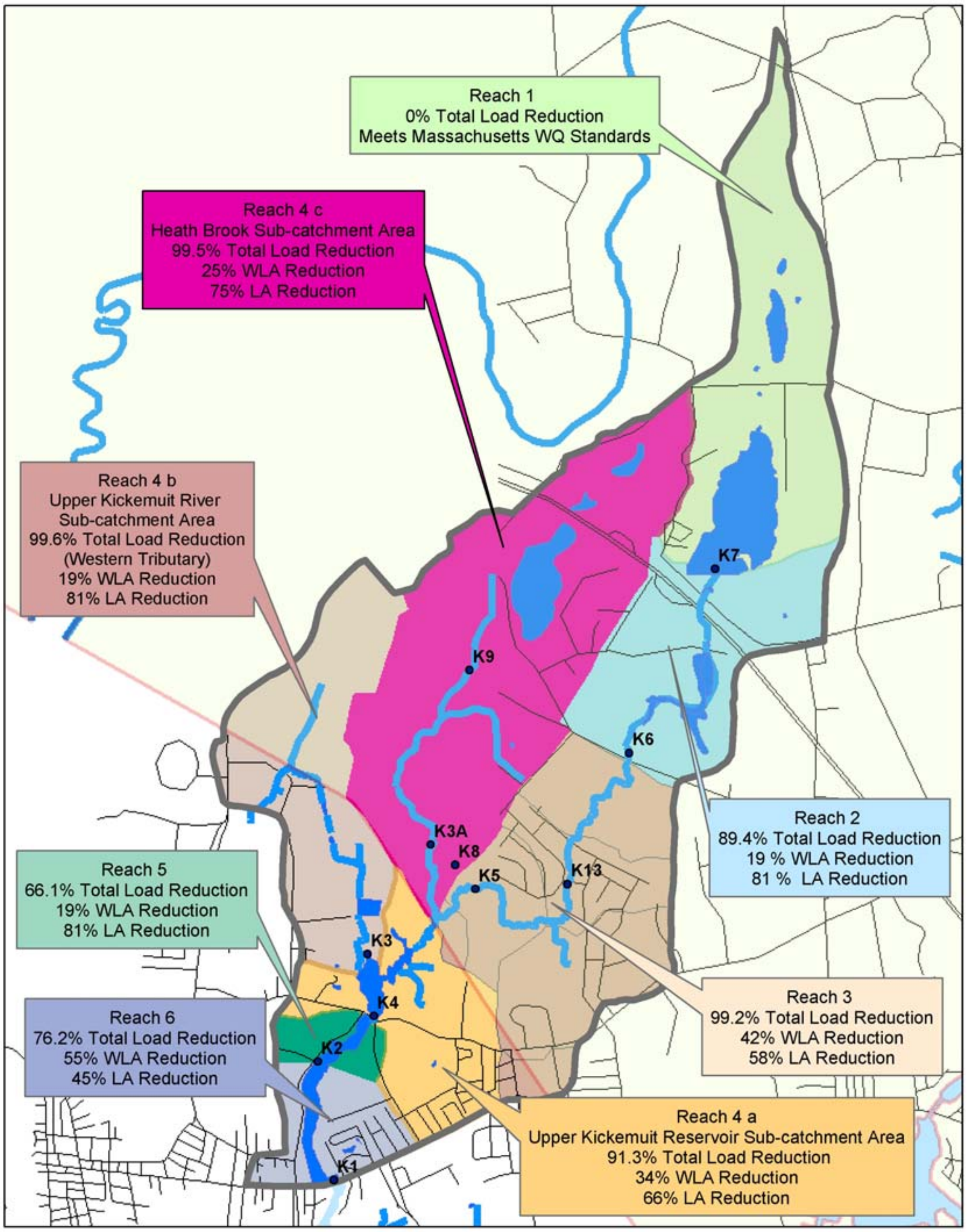
The Kickemuit and Upper Kickemuit Rivers, and the Upper and Lower Kickemuit Reservoirs were segmented based on contributing watersheds and data collection locations. Figure 4.1 shows the contribution areas to each segment. Land uses in the contributing areas to each segment were analyzed for uses that are primarily impervious or pervious so that waste load allocations and load allocations could be calculated and assigned to the contribution area. Table 4.1 also summarizes the total load reduction and its apportionment between the waste load allocation and the load allocation; these load reduction requirements and allocations are also summarized for each contribution area on Figure 4.1. For example, at sampling station K6 representing reach 2, the geometric mean concentration was 976 MPN/100 ml and the 90th percentile concentration was 3770 MPN/100ml. The 90th percentile standard is the limiting criterion, so a load reduction of 89.4% is needed to meet both parts of the standard. The contributing area to this segment of the Kickemuit River is shown on Figure 4.1 as reach 2. The area encompasses approximately 396 acres of which 323 acres are considered pervious (cropland, forest, open land, open parks, etc.) and 74 acres impervious (transportation (roads), industrial, residential). Assuming that all the area within these developed uses is impervious incorporates an implicit margin of safety since some percentage of the land area would most likely be lawns, grass areas or unpaved surfaces, allowing for some permeability. This conservative approach would overestimate the stormwater improvements necessary to improve water quality. The ratio between the impervious and pervious areas and the total contributing area is used to establish the relative contributions of point (WLA) and nonpoint (LA) source reductions to the total load reduction as summarized in Table 4.1.

Table 4.1 Fecal Coliform calculated reductions

Segment Name	Station ID	Target Geomean MPN/ 100ml	Observed Geomean	Target 90th percentile	Observed 90th percentile	Required Reduction %	**Percent load reduction via WLA (%)**	**Percent load reduction via LA (%)**
Reach 1: Kickemuit River @ Warren Reservoir Outlet	K7	200	7	400	25	**0%** Meets MA WQS	N/A	N/A
Reach 2: Kickemuit River – Upper MA	K6	200	976	400	**3770**	**89.4%**	19	81
Reach 3: Kickemuit River - Lower MA	K5	20	**2785**	200	15000	**99.3%**	42	58
Reach 4c: Heath Brook @ MA / RI Border	K9 K3A	20	2180	200	**44100**	**99.5%**	25	75
Reach 4b: Upper Kickemuit River (Western Tributary)	K3	20	**4899**	200	12500	**99.6%**	19	81
Reach 4a: Upper Kickemuit Reservoir	K4	20	134	200	**2300**	**91.3%**	34	66
Reach 5: Upper Reach Lower Kickemuit Reservoir	K2	20	**59**	200	396	**66.1%**	19	81
Reach 6: Lower Reach Lower Kickemuit Reservoir	K1	20	**84**	200	780	**76.2%**	55	45

Note: Bold values indicate reduction requirement governing criteria.

Figure 4-1 Map of Fecal Coliform Load Reductions and Pollutant Source Allocations by Reach and Sub-catchment Area



Total Phosphorus

The primary goal of the Total Phosphorus TMDL is to address the water quality impairments in Kickemuit Reservoir (upper and lower segments) associated with excessive phosphorus loadings including excess algal growth/chlorophyll a, taste and odor, and turbidity. Watershed pollutant loading and receiving water computer modeling tools were used in determining existing loads and allocations for total phosphorus in the upper Kickemuit watershed (NES, 2002), and are presented in Table 4.2. Three subwatershed areas of the upper segment of the Kickemuit Reservoir were evaluated for phosphorus reductions (Kickemuit River including Heath Brook, Western Tributary, and direct inputs). Consistent with Rhode Island's water quality standards that require that tributaries discharging to impoundments should not cause exceedance of the numeric criteria (25 ug/L) at the point of discharge, all of the necessary reductions were allocated to the Kickemuit River and the Western Tributary. Because the direct drainage area immediately surrounding the reservoir is undeveloped, has no stormwater outfalls, and provides a relatively good buffer from surrounding land uses, no reduction were allocated to this potential source area.

TMDL allocations for the lower segment of the Kickemuit Reservoir were distributed among three source areas (Shad Factory pipe, discharge from the upper reservoir, and direct inputs). Assuming that the discharge from the upper reservoir meets 25 ug/L, the only remaining sources include the Shad Factory pipe and direct inputs. For purposes of being both practical and equitable, a 30% reduction in existing loading was applied to both sources.

Finally, it is important to acknowledge that all of the allocations presented in this TMDL are best estimates and may change as new information becomes available.

The apportionment of total phosphorus load reductions in Table 4.2 into a WLA and LA for each segment was made in a manner similar to that done for fecal coliform. The pervious and impervious area ratios are somewhat different because sources and contributing areas were defined differently. These corresponding contribution areas of total phosphorus loadings are shown in Figure 4.2. For example, NES (2002) combines loads from Heath Brook and the unnamed tributary to reach 4a with loads from reach 3 and combined reaches 5 and 6 in Table 4.2. In contrast, Heath Brook is identified individually as a bacterial source to reach 4a in Table 4.1. The allowable loads and division of source reductions into the WLA and LA are presented in Table 4.3.

Excess algal growth/chlorophyll a, turbidity, taste and odors

Allocations are not assigned for turbidity and taste and odor. As stated previously the total phosphorus criterion will be used as a surrogate for excess algal growth/ chlorophyll a, taste and odor and turbidity. It is believed that the reductions specified above for phosphorus will remedy these related impairments.

Table 4.2 Total Phosphorus load allocations

Waterbody Segment	Season	Flow Millions M^3 From Model Data	Existing TP Load (KG) (BES,2002)	Allowable TP Load (KG)	TMDL (KG)	Percent Reduction	MOS
Sources to Reach 4a:							
Kickemuit River (Including Heath Brook and unnamed tributary)	winter	3.03	107.09	75.75	68.18	36%	10%
	spring	1.81	87.48	45.25	40.73	53%	10%
	summer	0.52	43.81	13.00	11.70	73%	10%
	fall	0.94	64.64	23.50	21.15	67%	10%
	annual	6.30	303.02	157.50	**141.75**	53%	10%
Upper Kickemuit River (Western Tributary)	winter	0.42	21.85	10.50	9.45	57%	10%
	spring	0.25	14.96	6.25	5.63	62%	10%
	summer	0.05	4.88	1.25	1.13	77%	10%
	fall	0.13	10.02	3.25	2.93	71%	10%
	annual	0.85	51.71	21.25	**19.13**	63%	10%
Direct Inputs from Watershed	winter	0.43	20.93	20.93	20.93	0%	
	spring	0.26	12.90	12.90	12.90	0%	
	summer	0.06	4.59	4.59	4.59	0%	N/A
	fall	0.12	11.75	11.75	11.75	0%	
	annual	0.87	50.17	50.17	**50.17**	0%	
Loss to Sediments Upper Kickemuit Reservoir	winter	N/A	-3.18		-3.18		
	spring	N/A	-6.55		-6.55		
	summer	N/A	-13.16		-13.16		N/A
	fall	N/A	-8.90		-8.90		
	annual	N/A	-31.79		**-31.79**		
Reach 4a: Upper Kickemuit Reservoir	winter	3.88	149.87	97.00	95.38	36%	
	spring	2.32	115.34	58.00	52.70	54%	
	summer	0.63	53.28	15.75	4.26	92%	
	fall	1.19	86.41	29.75	26.93	69%	
	annual	8.02	404.90	200.50	**179.26**	56%	11%
Sources to Reaches 5 and 6:							
Contribution of Upper Kickemuit Reservoir to Lower Kickemuit Reservoir (Total load minus sink)	winter	N/A	146.69		95.38	35%	
	spring	N/A	108.79		52.70	52%	
	summer	N/A	40.12		4.26	89%	
	fall	N/A	77.51		26.93	65%	
	annual	N/A	373.11		**179.26**	52%	
Direct Inputs from Watershed (Including stormdrains)	winter	0.24	12.67		8.87	30%	
	spring	0.14	6.15		4.31	30%	
	summer	0.05	2.67		1.87	30%	
	fall	0.07	7.44		5.21	30%	
	annual	0.50	28.93		**20.25**	30%	
Shad Factory Pipe	winter	0.24	7.99		5.59	30%	
	spring	0.34	23.02		16.11	30%	
	summer	0.70	37.97		26.58	30%	
	fall	0.49	16.37		11.46	30%	
	annual	1.77	85.35		**59.75**	30%	
Losses to Sediments Lower Kickemuit Reservoir	winter	N/A	-9.97		-9.97		
	spring	N/A	-17.60		-17.60		
	summer	N/A	-23.34		-23.34		
	fall	N/A	-18.95		-18.95		
	annual	N/A	-69.85		**-69.85**		
Reaches 5 and 6: Lower Kickemuit Reservoir	winter	4.36	167.35	109.00		35%	
	spring	2.80	137.96	70.00		49%	
	summer	1.38	80.76	34.50		57%	
	fall	1.75	101.32	43.75		57%	
	annual	10.29	487.39	257.25	**189.41**	61%	26%

Note: Loading capacities that are set on a seasonal basis. These loadings are assumed to be equally distributed over the course of a season, although loadings over a shorter time period may be critical to water quality in this system. This is most important during the growing season (Apr – Oct) when ambient temperatures are warm enough to promote nuisance growth of algae and other aquatic plants. Hydraulic residence times range from several days during winter and spring to approximately 2 weeks in mid-summer.

Table 4.3 Phosphorus load reductions by reach and source, and division of the reduction into the WLA and LA

Segment Name	Station ID	Receiving reach	Allowable Load (KG)	WL + LA Load reduction (%)	Percent load reduction via WLA (%)	Percent load reduction via LA (%)	MOS %
Reach 3: Kickemuit River	K5	4a	157.5	53	29	71	10
Reach 4b: Upper Kickemuit River	K3	4a	21.25	59	19	81	10
Direct inputs (source)	n/a	5 and 6	20.25	30	37	63	0
Shad Factory Pipe (source)	K10	6	59.75	30	100	0	0

4.5. Strengths and Weaknesses in the Analytical Process

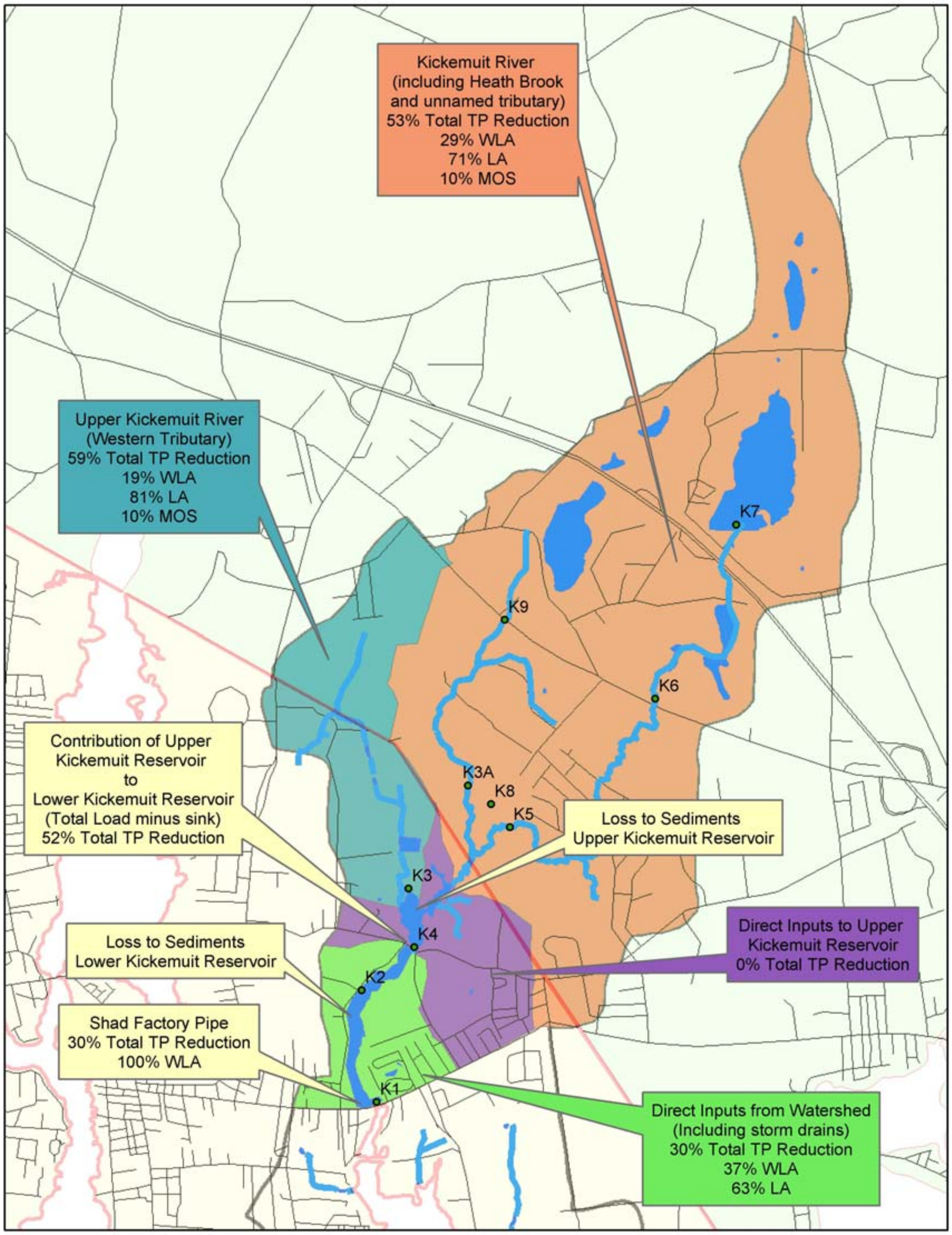
Strengths:

- The TMDL is based on an extensive knowledge of land use and potential bacteria and phosphorus sources in the watershed.
- A phased approach allows for an emphasis on mitigation rather than on more complex modeling to keep the focus on mitigating sources.
- The watershed is small and fairly accessible, therefore staff scientists were able to visually inspect nearly the entire length of the tributary streams and impoundments.
- The TMDL is based on actual bacteria data collected throughout the watershed during the summer of 2000.

Weaknesses:

- Greater uncertainty when compared to studies with extensive multi-year water quality monitoring data.
- Fecal coliform allocations were based upon instream sampling points, instead of the sources themselves. This was considered an acceptable approach in this watershed because: tributary streams were small in size, instream mixing was deemed to be rapid, dilution and die-off were deemed to be insignificant between sources and instream monitoring stations, and fecal coliform was routed through the instream sampling points.
- Turbidity data were not collected. TSS, Secchi depth and mean total phosphorus in the Kickemuit Reservoir were used as surrogate measures of the turbidity impairment.

Figure 4-2 Total Phosphorus contribution area map



4.6. Supporting documentation

Recent water quality studies considered significant to this study are presented in Table 4.4.

Table 4.4 Supporting documentation for the Kickemuit Reservoir TMDL Study.

Primary Organization or Authors	Title	Date of Report	Approximate Date of Study
NES	Preliminary Data Review and Proposed Monitoring Plan for the Kickemuit Reservoir TMDL Study	4/14/00	Spring 2000
USEPA	Kickemuit Reservoir Quality Assurance Plan (EPA/QA-R5)	4/26/00	Spring 2000
RIDEM	Data Assessment Report for the Kickemuit Reservoir TMDL Study	7/26/01	Spring 2001
NES	Development and Validation of Modeling Tools for the Kickemuit Reservoir	9/8/2002	2001-2002

5.0 IMPLEMENTATION

Implementation activities to restore Kickemuit River water quality focus on improved wastewater management, agricultural controls, and mitigation of storm water. Impairments to the Kickemuit River and Reservoir come from a combination of point and nonpoint sources during wet and dry weather. The sources included failing or substandard septic systems, agriculture, impervious surfaces, residential areas, waterfowl/wildlife and roadways. Pollutants are conveyed to the surface waters in storm runoff via storm drains, concentrated flow paths, and through sheet flows during and after rainstorms. Concentrations of all the pollutants were highest in the river after storms. Dry weather inflows containing significantly elevated fecal coliform concentrations are also conveyed to the upper river via storm drains. It can be concluded deductively that phosphorus, nitrogen, and fecal coliform loads are also conveyed to the river through groundwater flows and direct deposition. The sources would be agriculture and residential areas.

This TMDL relies upon a phased approach to an implementation plan to meet water quality goals. The corresponding response to reductions in total phosphorus and fecal coliform bacteria concentrations must be measured as remedial actions are implemented. Turbidity and Taste and Odor responses to source load reductions must also be measured as remedial actions are implemented. As may be appropriate, additional recommendations will be required if standards are not met as a result of the implementation plan presented within this TMDL.

Implementation recommendations are grouped into categories based on pollutant type and source and are listed below:

- Agricultural BMPs to reduce phosphorus loadings, fecal coliform bacteria concentrations and sediment loads in runoff, including education and public awareness programs on best management practices for fertilizing, sedimentation and erosion control, and other good agricultural housekeeping practices.
- Urban stormwater BMPs to control phosphorus and bacteria concentrations and reduction of sediment loads from runoff originating from streets and yards in the watershed.
- Reduction of Total Phosphorus and bacteria concentrations through proper operation and maintenance of on-site septic systems, and where feasible, construction of sanitary sewers to ensure proper disposal of wastewater.
- Public awareness and education on the benefits of good land use planning and good housekeeping activities to minimize impacts on water quality, including proper disposal of pet waste and other measures to discourage nuisance wildlife and waterfowl populations.

5.1. Agricultural BMPs

Four Rhode Island farms located on the west bank, the Lower and Upper Kickemuit Reservoir and in the upper watershed were identified as contributors of fecal and phosphorus loadings. These include:

a. A cattle pasture on the southwest corner of the Lower Kickemuit Reservoir in Warren, RI. The majority of this farm is located in the Palmer River watershed, however a small portion of the grazing area along Serpentine Road appears to drain east into the reservoir. During large rain events, runoff from this pasture washes directly into the Lower Reservoir in close proximity to the drinking water intake. RIDEM's Division of Agriculture is currently working with the farming operation on the west bank of the lower Kickemuit Reservoir to institute good housekeeping activities and proper manure controls.
b. A poultry and livestock operation located on Birch Swamp Road in Warren, RI in the Upper Kickemuit River (Western Tributary). Technical assistance from RIDEM's Division of Agriculture is needed to reduce this farm's impact on the tributary and downstream waters. During recent site visits by RIDEM, it was apparent that livestock are allowed direct access to this tributary. (See Figure 5.1) This farm also maintains a poultry operation that is located within 25 – 30 feet of the banks of the tributary. During the site visit, a dry weather grab sample taken downstream of the farm at the Birch Swamp Road crossing had a fecal coliform concentration of 49,000 MPN/100 ml. Necessary best Management Practices include proper manure control and disposal, restriction of access by livestock to the tributary, vegetative buffers along the stream bank for stabilization and protection from erosion.
c. Two farms located on Kinnicutt Avenue on the eastern banks of the upper and lower Kickemuit Reservoirs. The latter two farms produce nursery stock, fruit, vegetables and other bedding plants. According to RIDEM's Division of Agriculture livestock are not housed or raised on these two farms. Awareness of good housekeeping practices and proper control of sedimentation and erosion during the planting and harvesting of stock should be a priority for these two farms due to their proximity to the shores of the Kickemuit Reservoir. Best management practices in the application of fertilizers should also be observed to reduce the total phosphorus loadings to the reservoir. Riparian buffers consistent with NRCS guidelines should be established along the banks of the Kickemuit Reservoir to protect the reservoir.

Several other farming operations within the watershed, the majority of which are located within the Massachusetts portion also have the potential or are currently causing nutrient, bacteria and sediment impacts to the Kickemuit River and its tributaries. Of particular note is a farm where direct access of livestock to Heath Brook, just south of Route 6 in Swansea, Massachusetts is a concern. Again public education on the impacts that poor housekeeping practices have on these waterbodies is essential in reducing pollution from these sources. BMPs similar to those in Rhode Island should be implemented on farms in Massachusetts and will be referred to the Massachusetts Department of Agricultural Resources for appropriate follow-up.

Figure 5-1 Example agricultural source on unnamed tributary to Upper Kickemuit River (Western Tributary)

5.2. Stormwater BMPs

Phase II – Six Minimum Measures

Effective February 23, 2003, RIDEM amended the existing Rhode Island Pollutant Discharge Elimination System (RIPDES) regulations to include Phase II Storm Water regulations. On December 19, 2003, the RIDEM RIPDES Program issued the General Permit for Storm Water Discharge from Small Municipal Separate Storm Sewer Systems (MS4s) and from Industrial Activity at Eligible Facilities Operated by Regulated Small MS4s. This General Permit gave MS4 operators within regulated areas (i.e. designated municipalities) until March 18, 2004 to submit the Notice of Intent (NOI) and the Storm Water Management Program Plan (SWMPP). Since the entire portion of the Kickemuit River watershed in Rhode Island is located in a regulated area, all operators of MS4s in the watershed will need to comply with the regulations. The MS4s that discharge directly to the Kickemuit River and its tributaries are owned and operated by the Town of Warren, and the Rhode Island Department of Transportation (RIDOT). Correspondingly, the State of Massachusetts issued their general permit on May 1, 2003. In

Massachusetts, the Town of Swansea and MassHighway will also need to comply with these regulations.

Operators must describe Best Management Practices (BMPs) for each of the following six minimum control measures:

- A public education and outreach program to inform the public about the impacts of storm water on surface water bodies,
- A public involvement/participation program,
- An illicit discharge detection and elimination program,
- A construction site storm water runoff control program for sites disturbing 1 or more acres,
- A post construction storm water runoff control program for new development and redevelopment sites disturbing 1 or more acres, and
- A municipal pollution prevention/good housekeeping operation and maintenance program.

The SWMPP must include measurable goals for each control measure (narrative or numeric) that may be used to gauge the success of the program. It must also contain an implementation schedule that includes interim milestones, frequency of activities and reporting of results. The RIDEM Director can require additional permit requirements based on the recommendations of a TMDL.

Specific Storm Water Measures

To realize water quality improvements in the Kickemuit River and the Kickemuit Reservoir, both the pollutant concentrations in storm water *and* the volume of storm water discharged to the river and its tributaries must be reduced. Impervious areas in the watershed cause substantial increases in the amount of water and pollutants entering the Kickemuit River and Reservoir following rain events. As the amount of impervious area in a watershed increases, the peak runoff rates and runoff volumes generated by a storm increase because developed lands have lost much or all of their natural capacity to delay, store, and infiltrate water. As a result, phosphorus, bacteria, and suspended material from livestock, domestic pets, and other animals quickly wash off during storm events and discharge into the adjacent waterbodies. As represented by 2000 monitoring data, some tributary streams were not flowing during dry weather, but had measurable flows during wet weather.

Due to the substantially large phosphorus, bacteria, and suspended sediment load that needs to be reduced in order to meet water quality standards, as previously mentioned, both water quality and water quantity reductions must be addressed. RIDEM recommends the use of BMPs that reduce both pollutant loads *and* volumes to the maximum extent feasible. There are many opportunities to address both water quality and water quantity and tailor efforts to the local concerns in the SWMPP as outlined below:

Public Education/Public Involvement

The public education program should focus on both water quality and water quantity concerns within the watershed. Public education material should target the particular audience being addressed. For example, the residential community should be educated about the water quality impacts associated with their activities and the measures they can take to minimize and prevent these impacts. Examples include informing residents about the proper disposal of pet waste and yard waste, and the proper use of fertilizers. Public involvement programs should actively involve the community in addressing these concerns. Involvement activities may include stenciling storm drains with *Do Not Dump* labels and designating and maintaining areas with pet waste bags and containers.

The residential community should also be informed about water quantity impacts caused by large impervious areas and the measures to minimize or help offset these impacts. Measures include the infiltration of roof runoff where feasible and incorporating landscaping choices that minimize runoff. Some examples of landscaping measures are grading the site to minimize runoff and to promote storm water attenuation and infiltration, reducing paved areas such as driveways, and use of porous driveways (cost effective options may include crushed shells or stone). Runoff can also be slowed by buffer strips and swales that add filtering capacity through vegetation. These examples can also be targeted to residential land developers and landscapers.

Other potential audiences include commercial property owners, land developers, and landscapers. BMPs that minimize runoff and promote infiltration should be encouraged when redeveloping or re-paving a site. Examples include porous pavement, infiltrating catch basins, breaking up large tracts/areas of impervious surfaces, sloping surfaces towards vegetated areas, and incorporating buffer strips and swales where possible.

Illicit Discharge Detection and Elimination

Storm drains serving the Smoke Rise development were observed to be flowing during the 2003 dry weather survey. The dry weather flows may originate from direct connections (e.g., wastewater piping either mistakenly or deliberately connected to the storm drains) or indirect connections (e.g., infiltration into the MS4 of contaminated groundwater from cracked, failing, or improperly functioning septic systems, or curtain drain discharges containing contaminated groundwater). Currently this area is not slated for the installation of sanitary sewers. Stormwater outfalls in the Smoke Rise development should be prioritized for illicit discharge detection and elimination. Other densely developed areas in the watershed that contain storm drains should also be targeted for illicit discharge detection and elimination.

Construction/Post Construction

Storm water volume reduction requirements for development and redevelopment of commercial and industrial properties should be considered in the development of ordinances to comply with the construction and post construction minimum measures (see RI General Permit Part IV.B.4.a.1 and Part IV.B.5.a.2 respectively and Massachusetts General Permit Part II.B.4(a) and Part II.B.5(a) respectively). As mentioned previously, examples of acceptable reduction measures include reducing impervious surfaces, sloping impervious surfaces to drain towards vegetated areas, using porous pavement, and installing infiltration catch basins where feasible. Other reduction measures to consider are the establishment of buffer zones, vegetated drainage ways, cluster zoning or low impact development, transfer of development rights, and overlay districts for sensitive areas.

Good Housekeeping/Pollution Prevention

The Rhode Island Storm Water General Permit (see Part IV.B.6.a.2 and Part IV.B.6.b.1) extends storm water volume reduction requirements to operator-owned facilities and infrastructure (RIDEM, 2003a). Similarly, municipal and state facilities could incorporate measures such as reducing impervious surfaces, sloping impervious surfaces to drain towards vegetated areas, incorporating buffer strips and swales, using porous pavement and infiltration catch basins where feasible. In addition, any new municipal construction project or retrofit should incorporate BMPs that reduce storm water and promote infiltration such as the before-mentioned measures: buffer strips, swales, vegetated drainage ways, infiltrating catch basins, porous roads etc.

Stormwater Priorities for Municipalities and DOTs

As noted earlier in this report, there are numerous point and non-point sources of stormwater runoff to the river and reservoirs. EPA identified a total of 41 stormwater outfalls or other direct conveyances within the watershed. Fifteen outfalls discharge directly to the lower Kickemuit Reservoir, including nine storm drainpipes ranging in size from 8” to 16” in diameter, four hand dug channels constructed to divert runoff to the reservoir, and two points where overland flow is discharging from the adjacent roadway into the reservoir.

Roadways in the watershed, including Routes 6, 195, Serpentine Road, and the numerous local roads within the residential areas contribute phosphorus, bacteria and sediment loads to adjacent surface waters in storm runoff through direct conveyances that are regulated under the Phase II stormwater program. While the Storm Water Phase II minimum measures apply to the entire watershed, targeted retrofit activities should be phased in over time, focusing first on those discharges identified in Table 3.8 and shown on Figure 3.2 that discharge directly to the reservoirs. Design studies should evaluate means of distributing treatment structures within the watershed in addition to end-of-pipe solutions at the water’s edge.

This TMDL has identified WLA reductions required to reduce loadings to the Kickemuit River, Kickemuit Reservoir and their tributaries. Each responsible municipality or state agency must describe the Best Management Practices (BMPs) for each of the six minimum control measures mandated in the Phase II stormwater program. Measurable goals for each control measure must be included in order to gauge the success of the program. The development of the respective Stormwater Management Program Plans (SWMPPs) shall include an implementation schedule that includes interim milestones, frequency of activities and reporting of results. The plans shall contain provisions that address the systems identified within this report as contributing to a violation of the corresponding state’s water quality standards. Monitoring shall also be included to determine the need for additional measures following the implementation of the six minimum measures.

5.3. Septic Systems

The Massachusetts portion of the watershed along the Lower Kickemuit – MA reach contains the highest potential for pollution impacts from septic systems due to the presence of extensive high-density residential developments located adjacent to the river and the lack of a municipal sewer system. Of particular note is the evidence of failing septic systems in the Smoke Rise and Mont Fair housing developments. The Swansea Board of Health shall continue to institute the state’s Title 5 regulations, which requires the upgrading of failed septic systems at the time of property transfer. The use of advanced treatment systems that provide reduced nutrient and bacteria loads in effluent shall be encouraged in areas adjacent to the river or its tributaries. The town should also continue the monitoring and follow through on individual septic system problems and failures, particularly in these two housing developments adjacent to the river. Town of Swansea municipal officials responsible for planning and developing the town's municipal services should continue to support the construction of a sanitary sewer system where warranted within the watershed. This would be a permanent solution to reducing the impacts that the numerous improperly functioning systems have on the drinking water supply reservoir and its tributaries.

5.4. Land Use Activities

Water quality is a reflection of the land use activities and physical features of a watershed. These activities have significant, measurable impacts on phosphorus levels in surface waters. These levels are often associated with the use of phosphorus-based detergents, lawn fertilizers, stormwater runoff from developed areas, agricultural runoff, failing septic systems and pet waste. Public awareness of the benefits of good land use planning and good housekeeping activities in a watershed are critical elements of a watershed action plan. Planning and zoning strategies that use good site design, low impact or low density land uses in critical areas, and appropriate BMPs can effectively offset the impacts of development within the watershed. Pollution prevention techniques as opposed to pollution remediation or additional water treatment are the simplest and most cost effective approaches to protecting water supplies. The Town of Warren has begun this process by instituting a Kickemuit Reservoir Watershed Overlay District. This zoning control will be instrumental in regulating impacts of future development or redevelopment within the watershed. As technologies and methods for controlling water quality impacts evolve and improve, the updating of municipal land use plans and corresponding zoning and land development ordinances should follow suit. The Rhode Island and Massachusetts towns within the Kickemuit watershed should take full advantage of all opportunities that become available for bringing new performance standards in line with updated pollution control measures and practices.

5.5. Waterfowl, Wildlife, and Domestic Pets

Numerous studies have shown that waterfowl, wildlife, and domestic pets contribute significantly to elevated bacteria concentrations in surface water. RIDEM Fish and Wildlife Regulations prohibit feeding wild waterfowl throughout the state (RIDEM, Nov. 2003). The Kickemuit watershed communities should address the importance of picking up after pets and not feeding birds in their education and outreach programs. Pet wastes should be disposed of away from the waters within the Kickemuit watershed and any storm water system that discharges to any of these locations. Educational programs should emphasize that not cleaning up after pets and feeding waterfowl, such as gulls and geese, contributes to water pollution.

Towns and residents can take several measures to minimize bird-related impacts. They can allow tall, coarse vegetation to grow in areas along the shores of the reservoir that are frequented by waterfowl. Maintaining an uncut vegetated buffer along the shore will make the habitat less desirable to geese and encourage migration. Residents should also stop feeding birds. Eliminating this practice will decrease summer bird populations and make the area less attractive to the year-round residence of migratory birds.

5.6. Summary

RIDEM and MADEP will continue to work with RIDOT, MassHighway, HEALTH, BCWA, SRICD, NRCS and the local municipalities to identify funding sources and evaluate locations and designs for storm water control BMPs throughout the watershed. Table 5.1 summarizes the recommended implementation activities for all communities within the Kickemuit watershed.

Table 5.1 Implementation Measures Summary.

Abatement Measure	Jurisdiction/ Location	Notes
Storm Water Management	RIDOT MassHighway Warren, RI Swansea, MA	Phase II Stormwater Management Plans submitted and general permits as required which include six minimum measures and prioritization of outfalls for BMP construction.
Future Development and Redevelopment	Warren, RI Swansea, MA	Local ordinances should institute storm water volume reduction requirements for redevelopment of commercial and industrial properties.
Proper Wastewater Treatment	Swansea, MA	Extend or build sanitary sewers where feasible and prioritize areas of known problems. Continue implementation of Massachusetts Title 5 requirements.
Agricultural BMPs	Private Property Owners RIDEM Division of Agriculture, Massachusetts Department of Agricultural Resources	Good housekeeping practices, proper control of sedimentation and erosion, manure controls, BMPs for proper fertilizer application, restrict access by livestock to tributaries and vegetative buffers.
Educational Programs on Pollution Prevention and good Housekeeping Practices	RIDOT MassHighway Warren, RI Swansea, MA	Do not feed birds, clean up pet waste, plant buffers along the water, etc.

6.0 PUBLIC PARTICIPATION

A public meeting will be held following the EPA initial review when the draft Kickemuit River TMDL is presented for public review and comment. Following the presentation, the public will have a 30-day period in which to submit comments on the study and its findings.

7.0 FOLLOW-UP MONITORING

This is a phased TMDL and, as such, additional monitoring is required to ensure that water quality objectives are met as remedial actions are accomplished. Monitoring will be the principal method of obtaining the data necessary to track water quality trends in the watershed.

Periodic monitoring should continue at existing stations to ensure that progress is being made toward the water quality targets for the Kickemuit River. Water quality stations K7, K6, K5, K8, K3A, K2, and K1 should be sampled on an ongoing basis to verify that loadings from the upper watershed are decreasing, and that the allowable loading targets for the Kickemuit River are being met. RIDEM and MADEP will work with the Bristol County Water Authority and local citizen advocates to begin this effort.

The measurements should include total and dissolved inorganic phosphorus, nitrate and ammonia, turbidity and suspended solids (TSS), and temperature. Sampling for the appropriate bacterial indicator (i.e. fecal coliform, e.coli, or enterococci) should be performed at each station. Dissolved oxygen and chlorophyll-a measurements should be included in the epilimnia of the reservoirs. The measurements should be made on an ongoing basis within the Kickemuit Reservoir to directly measure the water quality trend as it responds to remedial actions taken in the watershed.

8.0 REFERENCES

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